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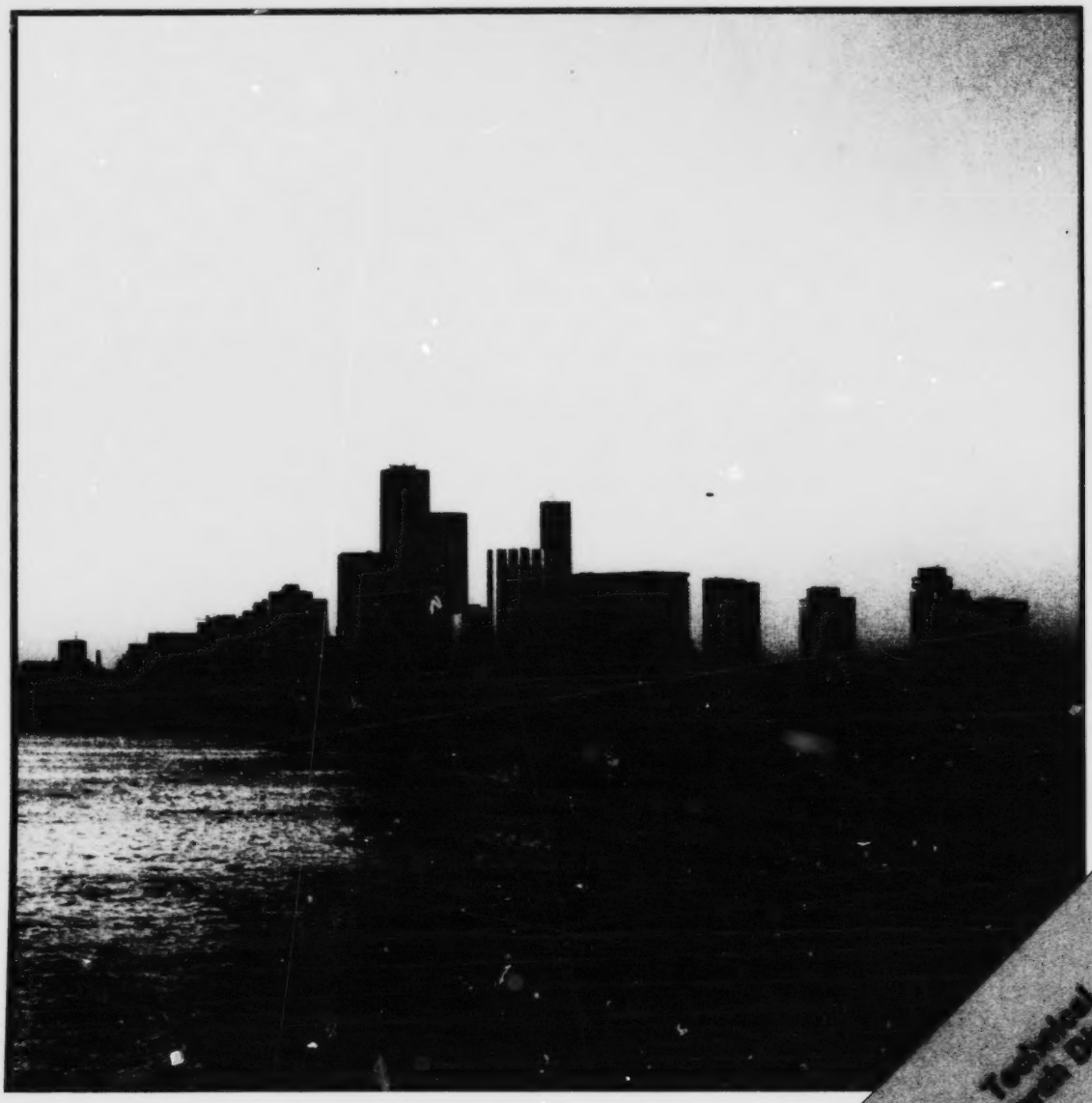
Renewable Energy At Your Doorstep

Freecool Project Toronto, Ontario



Technical Research Division

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April 12, 1982

Mr. Peter Favot,
Director,
Technical Research Division,
Canada Mortgage & Housing Corporation,
Montreal Road,
Ottawa, Ontario K1A 0P7.

Re: FREECOOL

Sir:

I have the pleasure of submitting to you our final report on the above project, in agreement with the terms entered into with you on 19 May, 1980.

It has been a stimulating experience for us, as we progressed through the various investigations. The outcome appears to lay a sound foundation and justification for further work to be done on the subject.

I wish to express my appreciation for the assistance and encouragement we have received from so many people and especially from your staff.

R. T. Tamblyn
President
Engineering Interface Limited

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CMHC File No. 5962-7

FEASIBILITY STUDY

FREECOOL PROJECT

TORONTO, ONTARIO

Prepared for
The Technical Research Division
Policy Development & Research Sector
of
Canada Mortgage and Housing Corporation

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April 1982

This project was managed by Canada Mortgage and Housing Corporation and funded by the Interdepartmental Panel of Energy Research & Development (PERD), but the views expressed are the personal views of the author and no responsibility for them should be attributed to CMHC or PERD.

FOREWORD

The concept of using free, renewable energy from natural sources such as lakes, rivers, seas and aquifers to cool and heat buildings has considerable merit as an energy conservation option. Recognizing this, the federal Interdepartmental Panel on Energy Research and Development funded this study, managed by the Canada Mortgage and Housing Corporation, to explore this concept in a specific location to assess its economic and technical feasibility.

Engineering Interface Limited was engaged by CMHC to investigate this concept in Toronto due to the favourable conditions of permanently cold water at the bottom of Lake Ontario in close proximity to a major urban area.

The Freecool Feasibility Study examines a totally integrated heating and cooling system embracing technologies associated with accessing natural cooling sources, district heating, thermal storage and load management. Consequently, this study has applicability in whole or in part to other major metropolitan areas in Canada where the natural cooling source could be a lake, river, sea or aquifer.

The results of this preliminary feasibility study indicate that the Freecool concept is both technically and economically sound. Further studies will be necessary to optimize designs for this and other potential sites.

The cooperation and effort of all contributors to this study is gratefully acknowledged.

Technical Research Division
Canada Mortgage and Housing Corporation.

FREECOOL ABSTRACT

Freecool involves the concept of pumping cold water from the lake bed of Lake Ontario through an hydraulic and heat transfer system to cool major downtown Toronto buildings.

A companion concept to Freecool, is collecting rejected heat from buildings which is then transferred through a chiller/heat pump system and stored for subsequent use in the buildings.

This preliminary study indicates that both cooling and heating concepts are technically and financially feasible.

CREDITS AND ACKNOWLEDGEMENTS

An advisory committee of persons, with special knowledge and experience in large energy projects was formed when this feasibility study was begun. The generous contributions of their time and experience are gratefully acknowledged. The members of the Advisory Committee are:

Mr. Peter Favot (Chairman) Director Technical Research Division	CMHC
Mr. George Milne Oxford Development Group Ltd. Y & R Properties Ltd.	Building Owners and Managers Association of Metropolitan Toronto
Mr. Ray Bremner Commissioner Department of Public Works	City of Toronto
Dr. Ian H. Rowe Assistant Deputy Minister	Ministry of Energy, Ontario
Mr. Roy Waters Energy Studies Engineer (Co-Generation Systems)	Ontario Hydro
Mr. J.C. Lowry Director Consumer Services	Toronto Hydro Commission
Mr. Ernest Griffiths General Manager	Toronto Harbour Commission
Mr. E.P. Irwin Conservation and Renewable Energy Branch	Department of Energy Mines and Resources Canada
Mr. R.T. Tamblyn	Engineering Interface Ltd.

This study would not have been possible without the close cooperation and encouragement of CMHC and without important contributions from several other organizations including:

1. Peat Marwick and Partners

Data of an essentially technical nature has been arranged by Peat Marwick and Partners to present the potential financial implications of Freecool in a way which would be best understood by potential owners and operators of the system. Other useful input from this source involved the presentation of likely tax and insurance costs for the project. Peat Marwick are not responsible for the validity of the initial and operating costs of the system from which their projections have been made, or for the selection of base line assumptions.

2. Proctor and Redfern Ltd.

The engineering design and costing for basic civil works, including tunnelling, storage tanks, building structures, pumps and primary electrical transformation has been contributed by Proctor and Redfern Ltd.

A more detailed report on these considerations is available upon request.

3. National Water Institute

A major and gratuitous contribution to the study has been made by the National Water Institute concerning temperatures of lakewater in the vicinity of the proposed Freecool intake. A comprehensive and definitive report on lakewater thermoclines for all seasons is available upon request.

Cover photo by Michael Gowling Productions Ltd.
Toronto, Ontario.

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1 - Freecool Analysis Computer Program.

2 - Financial Summary Printouts for Freecool Cooling by Peat Marwick and Partners.

3 - Financial Summary Printouts for Freecool Cooling and Heating by Peat Marwick and Partners

4 - Report on Civil Engineering Works by The Proctor & Redfern Group

5 - Summer Availability of Cold Lake Water Off Toronto - Environment Canada.

1.0 EXECUTIVE SUMMARY

Freecool for Cooling

Freecool is a concept for substituting the use of permanently cold water at the bottom of Lake Ontario for the chilled water which is presently generated by chillers in major downtown Toronto buildings.

Freecool for Cooling and Heating

A companion concept to Freecool, provides for the reuse of the redundant chillers. These would be purchased and reassembled at a central location to provide a heating function for Freecool. The chillers would accomplish this by elevating the heat discarded from the buildings through their chilled water, to a useful heating temperature of 50 C. This reclaimed heat would be stored and recirculated back to the heating systems in the buildings for an electrical energy cost as little as a third the price of central steam. The buildings served by Freecool could have approximately 58% of their annual heating loads provided by this heating process.

The cooling and heating side of Freecool have been analyzed separately, as a stand alone project for cooling only and as a combined cooling and heating project.

Energy Conservation Benefits

Freecool would achieve energy conservation, both in electricity for cooling and natural gas for generating steam.

The lakewater pumps would require only 5% of the electric energy currently used by the electric chillers that would be replaced. By the year 2000, the reduction in electrical requirements would amount to 120 MW of demand and 235,000 MWh of consumption per year. The cost avoidance for this reduction in energy would be approximately $9,000,000.

The heating energy which could be generated through heat reclaim is 1,260,000 GJ. The price of electrical energy to generate this heat is $1.86/GJ compared with the customer price for steam of $7.54/GJ. The cost avoidance for this price differential in heating energy is approximately $7,100,000.

Use of Constant 1981 Dollars

For clarity, the costs of Freecool, whether capital or operational, are expressed, throughout this report, in constant 1981 dollars, regardless of their year of application.

Capital Cost of Freecool

The estimated capital cost of Freecool is $62,000,000 for the cooling function or $142,000,000 for the combined heating and cooling functions. However, the Freecool customers would benefit from a net reduction in capital expenditures for building systems. This reduction in expenditures is estimated to be $19,000,000 for the cooling function and $28,000,000 for the combined heating and cooling functions. Major reductions of cost, to the customers, result from eliminating the need of future replacement of chillers in existing buildings and purchasing chillers and heating systems for new buildings.

A major cost for the cooling function of Freecool would be the cost of the 6 km long intake tunnel under Lake Ontario. This length is required to achieve a depth of 80 m in order to be assured of $4^{o}C$ water.

A major cost for the heating side of Freecool would be the construction and assembly of tanks, chillers and pumps at a suitable central location.

Freecool Pumping Station for Lakewater

The Freecool system, for cooling, requires that an underground pumping station be located as close to the distribution system as possible. For the base case, this is assumed to be in Toronto Harbour Commission land adjacent to the Harbour Castle Hotel.

From this location the water would be pumped through a drilled tunnel 20m under the Bay Street road allowance. Connections would be made to building complexes in each block from this tunnel. One of the favourable features of the concept is that street traffic will be disturbed only at these locations long enough for the connection to be made.

Freecool Heating Plant

The Freecool system for heating requires a one hectare site for the location of three 64,000 m^3 (17,000,000 US gallons) storage tanks, two for chilled water and one for hot water, and a plant to house chillers and recirculation pumps. In the base case an underground site has been chosen for this. It is presently owned by the City of Toronto and located at the foot of Bay Street.

The distribution of hot water to the buildings would parallel that of chilled water.

Financial Summary

A financial analysis for the base case was performed, based on the financial assumptions listed in Table 5 Section 10. The analysis was performed to examine the financial returns from three perspectives:

- Total system (of interest to government)
- Customers
- Freecool utility (of interest to a potential Owner/Operator)

Internal rates of return are relatively low until the year 2000, rise to the year 2015 and stabilize thereafter.

For the base case, the internal rates of return and simple payback periods are as follows:

Internal Rate of Return (IRR) %

	System		Customers		Freecool	
Year	Cooling Only	Heating &Cooling	Cooling Only	Heating &Cooling	Cooling Only	Heating &Cooling
2000	18	18	25	45	15	11
2015	22	23	28	46	21	17
2030	23	24	28	46	21	20

Simple Payback Periods

6 yrs.	6 yrs.	4 yrs.	2 yrs.	7 yrs.	8

Sensitivity Analysis

A sensitivity analysis was performed to review the impact of varying assumptions, both favourable and unfavourable. These include rates of inflation and energy escalation, the impact of taxes, cost overrun and the potential of reduced sale. These studies indicate that, for reasonable changes in baseline assumptions, real rates of return vary only moderately.

Future Studies

Further studies should address the most critical areas. These include the definition of a rate structure which would attract customers while treating original and subsequent customers equitably. Other key areas include the approval of taxing authorities to grant municipal corporation tax status (to the utility) and more precise definition of concessions which should accrue to such an energy conserving facility.

Further Opportunities for Freecool

Conservative estimates of customer load and system cost were made but at the same time, a list of assumptions which could improve the benefits of Freecool are given in Section 13. An example is the concept of using Freecool excavation material for the creation of four hectares of harbourfront land. Zoned for high-rise residential, such an extension of existing property could create a real estate asset of some $50,000,000.

Future Course of Action

The study of Freecool, to date, has been undertaken to examine technical and financial feasibility in a preliminary way. While this provides encouragement to proceed further, the cost of the program dictates that further studies be undertaken in a way which gives priority to finding a potential investor and examining the fiscal climate for such an undertaking. An outline of further work is shown in Section 12.0.

Freecool Timetable

Freecool could be available to its customers as early as the year 1987 for cooling and 1988 for heating if the engineering phase of this project were to begin before the end of 1982.

Labour Creation

Based on an average construction salary of $30,000, the Freecool project would inject 4500 man years of work into the somewhat depressed Ontario employment situation.

Validation of Study

The economics of the cooling and heating side of Freecool have been evaluated on the basis of the prelimiinary studies carried out for this report. The results, as proposed, prove that both concepts are viable, technically sound and worthy of further study.

Footnote

This report has adopted conservative assumptions for energy escalation. Now, at its time of release, higher values are under consideration by the two critical energy suppliers.

If central steam were to bear a surcharge of $2.00/mlbs., starting in 1983, to pay for system interconnections, there would be a decrease in simple payback of one year and an increase in IRR of 1% for Freecool Cooling and Heating.

If electricity escalates at 14%, 16% and 14% in the years 1983-85, as considered in one Hydro rate strategy, there would be a decrease in simple payback of one year and an increase in IRR of 2% for Freecool Cooling.

2.0 INTRODUCTION TO THE FREECOOL CONCEPT

2.1 Cooling Function

The name Freecool derives from the fact that Nature has provided a freely accessible, large, annually replenished reservoir of 4°C water below the 80 m depth in Lake Ontario.

With Freecool, this water would be pumped to the chilled water cooling systems in downtown Toronto, which have been designed to operate with 5 1/2°C water*.

The lakewater pumping system can replace the cooling function of many water chillers, using less than 5% of the energy required to operate the on-site refrigeration cycles.

The total reduction in electrical consumption would be approximately 235,000 MWh/yr. and the reduction in downtown electric demand, 120 MW. Although Toronto Hydro has a summer peaking problem in downtown Toronto, the demand shaving would not defer new generation for Ontario Hydro, because its system has surplus capacity in summer. The current transformation shortfall** in downtown Toronto would be alleviated, however, for the near term.

The locations of Freecool intake, pumping station and supply water trunk below Bay Street are illustrated on Figure 1.

2.2 Heating Function

The cooling phase of Freecool provides a supply of lakewater which is distributed to 20 or more major buildings adjacent to Bay Street. This pipe tree would pick up the rejected heat from the cooling systems through basement-mounted heat exchangers and deliver it to an outlet in Toronto Harbour at a temperature of 12°C.

There would be enough heat returning to the Lake in the chilled water system to exceed the 24 hour heating requirements of the same buildings until the outside temperature drops to a daily average of -1 °C.

Furthermore, the electricity cost of reclaiming this waste heat, elevating it to 49°C, and recirculating it back to the customers as hot water, is less than $1.86/GJ*** in 1981, or about 30% of the present price of steam provided by the existing Toronto Hydro System.

* Many are now being operated at 7° C to reduce energy input to the chiller drives.

** Additional capacity for the Orde Street station has been under review for several years, at a cost of $4,000,000 approximately.

*** Based on an off-peak electric rate of 2-1/4¢/kWh.

The favourable economics of heat reclaim have led to an extension of the Freecool system concept to provide 58 percent of the annual fabric and ventilation losses* of its customers with recirculation of their own waste heat.

The additional equipment for the heating side of Freecool consists of a 56,000 ton chiller plant for reclaiming heat, two 64,000 m^3 storage tanks to contain returning chilled water and one 64,000 m^3 tank to store hot water through a daily cycle. Recirculation pumps would also be added for hot and chilled water.

The saving for Freecool heating will be in the order of 1,260,000 GJ as noted in Figure #15.

2.3 Prospective Customers

Approximately 40 major buildings, located adjacent to Bay Street were investigated. Of these, all were included as customers if full-sized chilled water piping was found to exist at the basement level. A number of buildings with chillers at mid-height or topside were discounted, even though the interconnecting piping might be negotiated at a viable cost. All of the buildings which were investigated are tabulated later.

A further 40 buildings of smaller size may connect to the service, increasing the load estimate by up to 15%. These buildings have been discounted for the time being.

Since Freecool is unlikely to provide any service before 1987, a number of buildings, for which construction start in 1981 was planned, were added as a second grouping. Others which are likely to be complete by 1987 were noted in a third grouping. See Figure #2.

2.4 Timetable

The most likely timetable for Freecool, if no unusual delays take place, would be as follows:

---

* Heat losses through the building envelope are distinct from reheat for temperature control which currently amounts to a significant percentage of heating requirements, but which is expected to be eliminated from future heating needs.

	Cooling Only	Cooling and Heating
Preliminary Report	Apr. 1982	Apr. 1982
Review and Supplementary Studies	9 mos.	9 mos.
Concept Study	6 mos.	12 mos.
Review Period	6 mos.	12 mos.
Design and Working Drawings	6 mos.	12 mos.
Tender Period	3 mos.	3 mos.
Review Negotiation of Tender	3 mos.	3 mos.
Construction	30 mos.	30 mos.
Earliest Completion	1987	1988

2.5 Cost Avoidance Through the Use of Freecool

The annual cost avoidance in cooling would be approximately $9,000,000 as developed in Figure #34.

The cost avoidance in heating would approximate the 1,260,000 GJ/yr. noted in Figure #15 multiplied by the saving over central steam ($7.54-$1.86)GJ, as shown in Section 6.7, or $7,100,000/yr.

3.0 SCOPE AND OBJECTIVES

3.1 Scope

Until this study began, Freecool was merely an idea.

The overt manifestations were promising, as with many energy conscious schemes. But would the cost justify the promise? And what other pitfalls might be uncovered to blemish its potential?

Since many large scale conservation schemes have failed to justify their initial promise, it was prudent to treat Freecool with caution.

The scope of the project was therefore limited at the outset to a modest investment, enough to examine the perceived constraints and discover whether there was merit for a serious study.

In summary, the scope of this report is limited to a preliminary review of the potential for Freecool, to see if more work is warranted by the findings.

3.2 General Objectives

The prime objective of the report is to test the overall financial prospects of Freecool in a preliminary way.

Secondary objectives include an examination of technical hurdles and potential institutional and financial barriers. These are resolved where appropriate or flagged for further investigation during subsequent studies.

3.3 Specific Objectives

The process necessary to make a case for Freecool falls within the following areas for examination:

3.3.1 Examine initial hurdles such as cold water availability, land requirements and jurisdictional veto which might block the project.

3.3.2 Provide a preliminary design to assess the cooling and heating loads available to the system.

3.3.3 Provide an outline of the design suitable for preliminary costing of two potential systems, one for Freecool cooling only and one combining Freecool Cooling and Heating.

3.3.4 Derive the annual operating cost of the cooling and heating functions of Freecool.

3.3.5 Compare those operating costs with the status quo cost over the life of the system.

3.3.6 Present financial models of the economics of Freecool in a manner suitable for consideration and further action by potential owner/operators of the system. These models examine all the cash flows associated with the project and calculate net present value and rates of return on investment under varying assumptions of future demand, energy cost escalation rates and initial capital costs.

4.0 PRELIMINARY HURDLES

A number of potential problem areas for Freecool were investigated before the study was allowed to proceed. These are discussed below, along with steps taken to surmount initial objections.

4.1 Lakewater Temperature

Before commencing this report, it was necessary to ensure the reliability of a 4 ^{o}C water supply from Lake Ontario.

This was accomplished to a satisfactory degree through discussion with Farrell Boyce of the National Water Institute at Burlington, Ontario. His thermoclines for summer water temperature in Lake Ontario, based on earlier study, are shown in Figures 3, 4, 5 and 6. Further definition of thermoclines at depths up to 100 metres is given in Supplementary Report #5, entitled "Summer Availability of Cold Lake Water off Toronto", by Environment Canada.

A special temperature recorder was mounted at the approximate location of the proposed intake in the summer of 1980. The results of this survey are published in the above-mentioned report, and shown in brief in Figure 7.

In summary, the reliability of a 4^{o}C water supply in the principal cooling months of July/August seemed acceptable at a depth of 80 m. This located the intake approximately 6 km off shore. Reversal of surface temperature in September causes instability of temperature thermoclines. However, an acceptable 5 1/2 ^{o}C for September can be assumed. A depth of 100 m is required for assurance of 4^{o}C at all times of year.

4.2 Toronto Harbour Commission Approval

A meeting was held in the offices of the Toronto Harbour Commission, with three officers from THC and two from CMHC in attendance.

Conclusions reached at that meeting included:

4.2.1 That no serious impediment to Freecool was foreseen by THC.

4.2.2 That the Ontario Ministry of the Environment should be consulted in relation to ecological effects.

4.2.3 That Freecool excavation material (200,000 m^{3} in all) could not be used for the creation of land for waterside condominium buildings, but could be used, as later directed, to extend the Leslie Street spit.

4.2.4 That THC land could be used, in all likelihood, for Freecool civil works, if structures were finished below grade and reinforced to accept future above-grade structures.

In summary, no objection to Freecool was voiced which would preclude development of this project at this time.

4.3 Landsites

The possibility of using land controlled by the Toronto Harbourfront Corp. was reviewed. The best opportunity appeared to be two half hectare sites - the first, which is a parking lot alongside Terminal Warehouse, the other a lawn alongside the Terminal Warehouse slip. In a subsequent meeting, the parking lot had reverted to a proposed building site. The other site was relegated lower in priority, because of the cost of dewatering excavation alongside water of 7 m depth.

A portion of the Toronto Harbour Commission parking lot alongside the Campeau Convention Centre is now proposed for the main Freecool pumping station. See Figure 8. This would require some exposure above grade, in order to provide water surge depth, in case the pumps stop suddenly. If this site becomes unavailable, alternative sites may be considered on Toronto Island or "Freecool Island", an island created with Freecool fill.

The Freecool heating plant, consisting of storage tanks and chiller/pumping building is proposed below grade on the City of Toronto parking lot between the railway and the Gardiner Expressway.

Although the City Planning Commissioner, Stephen McLaughlin, has been contacted for information, there is, as yet, no understanding about the use of this site. If it is unavailable, other THC land in the general vicinity could be considered by adding a cost of $2,200/lineal metre for extending the header piping from Bay Street.

4.4 Environmental Considerations

Chilled water effluent to Toronto Harbour from Freecool will be at a temperature of approximately 2°C. Most of the ultimate 20 million m^3/yr. of Freecool flow will be discharged in the summer months when the bay water is within 10 °C of discharge temperature. In fact, more than 75% of annual flow may be within 5°C of the harbour water temperature.

Dr. Weiler of the Water resources Branch of the Ontario Ministry of the Environment, was contacted concerning his opinion of the prospects for Freecool temperature pollution and other contaminants. His reply is shown as Appendix A. In brief, he sees no overriding problem at this juncture, but must withhold a general blessing pending the receipt of a consultant's report dealing with several areas of concern. It is understood that such a report is not a minor matter from a fiscal point of view. It is liable to cost between $100,000 and $150,000 and, therefore, should be included in a subsequent phase of Freecool reporting.

It is the opinion of A. W. Stevens, a Toronto water treatment

consultant, that water drawn from an 80 m depth will be ideal for chilled water distribution, since it will contain no algae and be low in oxygen content. This differs from City water, which is drawn from a 12 m depth and which contains corrosive amounts of oxygen. See Mr. Steven's comments in Appendix B.

Since the Freecool piping is principally concrete and plastic and since the heat exchangers are stainless steel, water treatment of any kind may be avoided, thus adding little in the way of contaminant to the Harbour.

It is the E.I.L. opinion that, far from adding contaminants to Toronto Harbour, Freecool will dilute the contaminants which are already proliferating there and being complained about by sailors. The Freecool discharge is alongside the TTC Ferry Terminal, since this is currently an area of greatest water pollution.

4.5 Vested Interests

An advisory committee was formed, incorporating CMHC, the Federal Department of Energy, Mines & Resources, the Ontario Ministry of Energy, Toronto Harbour Commission, Toronto Hydro, Ontario Hydro, the City of Toronto and the Building Owners & Managers Association. Major purposes for the original meeting of delegates from these jurisdictions were to inform the delegates, secure their approval and check to see if any had objections sufficient to cancel the study. None stated any serious objection.

Toronto Hydro stands to lose revenues of $7,000,000/year, or 2% of total 1987 income, from the cooling function of Freecool, although new construction in the downtown area may replace this in other than cooling loads before Freecool would be operational.

Ontario Hydro would lose a similar sale of power, although it has the flexibility to divert this sale toward international customers who would be most needful of backup on the warm days when the sale is lost in Toronto.

The City of Toronto, if it owns the proposed new steam network, would lose some of the present sale of heat to downtown buildings, including future buildings, which would be connected to Freecool. However, it will be shown later that, the Freecool storage will have the capability of taking steam supplement from this system in a way which will reduce, rather than increase, investment in steam generation plant.

In several meetings with the Advisory Committee, none of the concerns outlined above was offered as a reason to abort the study.

5.0 DESCRIPTION OF BUILDING LOADS

The potential market for Freecool was estimated after consultation with the operating personnel in the Clients' buildings. The cooling loads for each building were obtained for several conditions ('hot day' in July, 'average day' in January, etc.), in addition to the periods of chiller operation. Loads were then correlated with meteorological data to obtain cooling profiles as a function of ambient temperature and time of day.

Heat profiles were obtained in a slightly different fashion. Single and double glazed buildings were assumed to have balance temperatures of 2 °C and -7 °C respectively. Since the heating requirement at the balance temperature is roughly one-quarter of the maximum cooling load and varies linearly with temperature, profiles could be developed for each buidling. Different load profiles were used for daytme and nighttime operation.

The results of the load survey are shown in Figures 2 and 9. A few buildings not able to utilize cooling from Freecool were considered as a potential market for heating. Since the amount of hot water which Freecool can provide depends directly on the amount of cooling water provided, buildings which can use this cooling water earn a prior right to low cost heating.

In addition, some of the cooling water customers cannot be heated satisfactorily with 49 °C water, the maximum temperature attainable from the heat pumps. Sheraton Centre, for example, requires 80 °C. Such buildings were not considered as heating customers even though a major fraction of their heating requirement could be met with 49 °C water.

The heating and cooling piping loops are shown in schematic form in Figures 10 and 11. These drawings illustrate a central spine which runs up Bay Street, with side branches feeding the various customers. Because of the extensive structure of interconnecting basements and parking lots beneath the buildings, it is more economical to supply a chain of customers from one main connection than to supply each separately from Bay Street. The connecting paths shown are tentative and subject to Owner approval, but represent an effective pipe routing.

Owing to the nature of the main supply tunnels, connections to them are readily made at the time of construction, and much more difficult afterwards, when the system is operating. Therefore, extra connections to serve future customers are envisaged at one block intervals. These branches would run into the basements of the nearest buildings, and terminate with a valve and blind flange. Future hook-ups would then be possible with no disruption of flow.

The heating and cooling profiles for each customer were used in conjunction with hourly temperature data obtained from the Department of Public Works to simulate building operation.

Supplementary Report #1 contains the FORTRAN computer program which was used in the analysis. This procedure made it possible to size the Freecool equipment (tanks, pumps, etc.) and provided a basis the for financial analysis of the project.

The results of the simulations are shown in Figures 12, 13 and 14. Figure 15 provides the monthly heating and cooling for each of the customer buildings. It should be noted that the figures for heating represent fabric losses only, and do not take into account any reheat loads. The latter are a measure of inefficiency in the mechanical systems and, in some cases, exceed the steam requirement for fabric losses. However, the reheat loads are expected to decrease as buildings are retrofitted for more energy conscious operation.

Figure 13 and 15 present the total heating and cooling loads on a month by month basis. In 1987, the cooling requirement varies from a maximum of 218,000 GJ in August to a minimum of 70,000 GJ in February. The annual load is 1,546,000 GJ. Of this total, about 65%, or 1,009,000 GJ, is provided directly from the Lake, while the balance is produced by the chillers during regeneration of hot water storage. If the Freecool project were to proceed without its heating function, all of the cooling load would be provided by the Lake. The ultimate capacity, planned for the year 2000, exceeds these data by 93%.

The 1988 heating loads on Figures 13 and 14 are subdivided into portions which can be met using reclaimed heat, and portions which must be met using back-up steam. Steam is required in significant quantities only between December and March. On a yearly basis, approximately 42% of the 1,151,000 GJ total load is provided by steam, while the other 58% (674,000 GJ) is provided by low cost reclaimed heat. The ultimate capacity planned for the year 2001 exceeds these data by 87%.

The maximum 1988 steam usage in any 24 hour period is found in Figure 14. This gives a measure of the load Freecool places on the central steam distribution grid. Daily (and not hourly) totals are significant, since heat can be put into the storage tank during the off-peak period and released during the day. The benefits of this strategy are based on low unit cost of heat, as derived in Section 7.7.

As expected, a significant demand for steam occurs only in the winter months from December to March. For example, the coldest day in January requires about 10,000 GJ of heating, or the equivalent of about 4.3 million kg of steam. The amount actually necessary from the steam grid is only 3.3 million kg - the remainder comes from Freecool. The scenario improves as the months get warmer, until June, when no back-up steam is required.

6.0 DESCRIPTION OF FREECOOL CONCEPT FOR COOLING (See Figure 16)

As outlined above, Freecool is a concept for replacing on-site water chilling plant with lakewater cooling from a central distribution system. In the case of existing buildings, the chillers would become redundant and can be sold to help pay for heat exchangers and to generate additional storage space. In the case of new buildings, Freecool would supplant the chillers from the outset, saving Owners approximately $\$10/m^2$ of conditioned space in their capital cost.

The system is sized to handle an initial load of approximately 899 GJ/h (71,000 tons) of cooling in 1987 with 7,600 l/s (120,000 USgpm) and to be readily expandable to increase this capacity to 13,000 l/s (200,000 USgpm) in 1988. The intake pump house, supply/return main, branch takeoffs and outfall are all oversized for the ultimate capacity, since these elements would be impossible to expand later.

In sequence of water traverse, Freecool consists of lakewater intake, intake tunnel, intake pumping plant, supply/return water header, supply/return water branch lines, heat exchangers, including meters and control, and water outlet spillway with harbour outfall. Some detail on each component is provided under the following sub-heading:

6.1 Lakewater Intake

This will be a large structure, mounted solidly on the rock floor of Lake Ontario, as illustrated in Figure 17. Silt would be evacuated from around the intake for a 50 m diameter. The fiberglas intake screen would be constructed at 150 mm centres to make blockage impossible with small objects. The intake velocity would be less than 0.1 m/s at maximum ultimate flow so that the intake energy should be insufficient to ventriculate warm lighter water from higher levels in the Lake. A study may be necessary later to ensure that the intake "draw" would be in a horizontal plane. See Supplementary Report #4 for more detail.

Work in placing the intake would be assisted by divers, who are able to function safely at this level using a helium/oxygen mixture in place of nitrogen/oxygen in their breathing apparatus.

6.2 Intake Tunnel

The sizing of this element relates to the overall friction at peak flow, which must not exceed 9 m (28 ft.) of equivalent water head in order to avoid cavitation at the pumps.

An inside pipe diameter of 2.9 m (9 ft.) can support maximum flow with a drawdown at the pumping station of only 7.75 m (24 ft.), for the maximum length of intake required, see Figure 1.

This calculation assumes a concrete lining in the intake tunnel, giving an assumed friction factor "C" of 120. The concrete lining,

although costing 25% of the average tunnel cost of $3,000/m, is worthwhile to make the rock boring permanent and to make the friction factor lower and of consistent value. The ultimate water velocity in the intake tunnel would approach 2.25 m/s (7 fps).

The tunnel could be sloped up from the intake to the pumping plant at a constant 1 1/2% gradient, or it could be sloped downhill from both ends to a bore-hole on Wards Island. It is difficult to say whether the downhill feature, combined with convenient dockage for barging the fill, would make the longer traverse worthwhile or not. The optimum tunnel routing can be determined during a future study phase.

The length, diameter and cost of the intake are sensitive to a final determination of necessary depth and allowance for future increase in flow. The following table illustrates potential savings for curtailing plant expansion and raising the intake depth. For further detail see Figure #35.

Intake Designation	Intake Length m	Intake Diameter m	Flow Rate m/s	Intake Cost Million$	Saving or Extra Over Base Million$
12.620 l/s (200,000 USgpm) @ 80 m depth (250 ft.)	6,290 (19,500 ft.)	2.9 (9.0 ft.)	2.25 (7 fps)	17.6	
12,620 l/s (200,000 USgpm) @ 100 m depth (320 ft.)	11,500 (37,700 ft.)	3.2 (10.5 ft.)	1.57 (5 fps)	41.1	+ 23.5
7.600 l/s @ 80 m depth	6,290	2.25 (7.0 ft.)	1.9 (5.8 fps)	12.5	- 5.1
25,200 l/s @ 100 m depth	11,500	4.19 (13.75 ft.)	1.8 (6.0 fps)	63.2	+ 45.6

Consideration has been given to laying the intake partially along the Lake bottom. Preparation of a smooth bedding for this scheme, however, is claimed to involve more cost than the bored tunnel solution described above.

6.3 Intake Pumping Plant

This has been positioned as noted in Figure #8, and it would include the following elements as detailed in Figure #18: rotating trash screen with bilge pumps, main intake well (13 m diameter x 26 m high), vertical axis turbine type pumps, head recovery turbines, inlet and outlet headers, constant back pressure valve, water treatment unit (if required) and overflow arrangement to box header outlet spillway to the harbour.

Pumps installed initially for 7,600 l/s (120,000 USgpm) would include:

2 - Variable speed units @ 950 l/s (15,000 USgpm)

2 - Fixed speed units @ 1,550 l/s (25,000 USgpm)

2 - Variable speed units @ 2,500 l/s (40,000 USgpm) (one full-time spare).

As well, two turbines would be installed on the return header to generate enough electricity to recover approximately 20% of pumping head. See Figure 19 and further detail in the Proctor & Redfern report - Supplementary Report #4. The total pump energy requirement would be 6,100 kW initially. Later, this would be expanded with the addition of two 1,000 l/s fixed drive pumps and two 1,600 l/s variable drive units for the ultimate Freecool water delivery of 12,620 l/s (200,000 USgpm).

6.4 Supply/Return Water Headers (See Figure 10)

A buried concrete-lined, lakewater supply conduit would be drilled up the Bay Street road allowance at a depth which would permit approximately 3 m rock cover over the crown. See Figure 20.

This conduit would be sized for the ultimate delivery capacity of the Freecool pumping station at a head of approximately 6 m water gauge in each direction. The conduit would consist of a 3.5 m, inside diameter, pipe, with a vertical partition to separate supply and return water flow.

At an appropriate location in each block, knockouts would be poured at the crown of the pipe to accept 750 mm (30 inch) diameter supply and return steel connection fittings.

A surge chamber would be provided at the Queen Street terminus of the conduit. At this location, there would also be a pressure sensor to control the output volume of the Freecool pumps.

At one time it was felt that a 5 m diameter utilidor would be a better conduit for insulated steel headers, two at 1.5 m diameter today, and two equal size units in the future. However, it was found that there was no secondary use for the utilidor and that the bored conduit for ultimate capacity was cheaper than the utilidor for initial capacity. Hence, the change in plan.

6.5 Supply/Return Water Branch Lines

In each of 9 City blocks there would be 750 mm vertical, prefabricated, supply and return connections to the lakewater

conduit. These would be dropped into boreholes augered from street level. At some elevation, which conflicts least with existing services, 600 mm horizontal headers would be carried below street level to the building basement on each side. At these locations, 600 mm branch isolation valves would be placed inside the basement wall. These valves obviate the necessity to drain down the main conduit for making new connections and permit Freecool to be permanently in service, once started.

From the 36 isolation valves thus installed, the branch services would be run in insulated PVC plastic pipe to the customer's basement-mounted heat exchangers.

There would be less expense and less street traffic interruption, if the branch piping remains within building basements from this point, rather than being run down side streets in open cut. However, in some cases, the lines would have to run through the basement of one customer to serve another. There is some precedent for this in the service headers of the London, Ontario District Steam Heating Plant, which feed through retail basements.

It may require a payment of some type to a customer if his basement is used to feed another customer. From preliminary discussions on this point, it would appear to involve a minor cost, with charges for "pass through" being paid by the beneficiaries at the end of the branch.

From Figure 10 it will be seen that the idea of pass through has been extended as far as the west side of University Avenue, where an under-street access tunnel would house the lines between the first and second phases of the Sun Life Office project.

For the most part, the Freecool headers would be hung along perimeter or mutual basement walls in order to avoid conflict with other services. A detailed examination of branch line routing would take some time and must await the next study phase.

PVC or ABS plastic pipe and fittings would be used inside the buildings because it is more anti-corrosive than steel, faster to install, less resistant to flow and approximately 30% cheaper, overall. This type of pipe is approved for up to 689 kPa (well over Freecool requirements) at the maximum system temperature of 49 ^{o}C.

6.6 Heat Exchangers

Lakewater could be pumped directly into building chilled water circuits, but this would require two expensive provisions, static head pumping to overcome the heavy pressure at the base of most piping systems, and the addition of a continual dosage of anti-corrosion chemicals to protect the inside surface of the steel piping in the buildings. For these reasons, and to keep building hydraulics separate from Freecool hydraulics, stainless steel cross-flow heat exchangers would be installed to take the place

of existing chillers.

The Freecool water would have risen from 4°C in the Lake to 4 1/2°C by the time it arrives at the heat exchangers. Half of this rise would take place at the pumps and half by way of heat gain through pipe walls. Since the customer buildings were designed for use with 5 1/2°C water, the heat exchangers must be sized for a 1°C approach. This relatively narrow value would adversely affect the size and cost of heat exchange, causing the cost to rise to approximately $16/MJ ($200/ton). If 7°C chilled water, as used today by energy conserving buildings, were acceptable, the approach rises to 2 1/2°C and lowers the size and cost of heat exchange by almost 50%. Figure 21 illustrates current costing of cross-flow equipment using #316 stainless steel.

A case can be made for suggesting that each customer purchase his own heat exchangers directly. If Freecool purchased this equipment it would become unnecessarily responsible for results within the customer's plant. Furthermore, Freecool would be in the position of having to produce 5 1/2°C water on the customer side of the heat exchanger, while the customer could elect to pay half as much for a 2 1/2 °C approach, yielding the 7 °C condition that some energy conserving operators are actually using. The performance of the heat exchanger is sensitive to a number of variables. For instance, 20% increase in flow on the lakewater side may narrow the approach in like percentage. Yet, detailed engineering might reveal that this had raised the Δp beyond the 18 m allowed by Freecool, so that a booster pump would be required to effect the savings. In summary, the performance of the heat exchangers is sensitive to cost and details peculiar to the customer's equipment. It has therefore been decided to divide installation responsibilities between Freecool and the customers as follows:

6.7 Freecool Responsibilities

6.7.1 Bring branch supply and return piping to within 10 m of the heat exchanger site.

6.7.2 Provide a meter and control valve sized to suit the customer's requirement for flow, assuming Freecool water is at a temperature of 4 1/2°C.

6.7.3 Wire the meter for remote reading.

6.8 Customer's Responsibilities

6.8.1 Dispose of present water chilling equipment, if this is desired to produce income or provide useful space.

6.8.2 Purchase and install the heat exchangers to suit local design requirements. Fortunately, the cross-flow type of heat exchanger may be purchased originally for a 2 1/2°C approach and then extended later to meet a narrower approach if such

is found necessary. See Figure 21 for current heat exchanger costing.

6.8.3 Mount the meter, flow control valve and sensor provided by Freecool.

6.8.4 Complete the piping and insulation required on both sides of the heat exchangers, complete with isolation valves, more or less as indicated in Figure 22.

6.9 Meters and Control Valves

Meters for Freecool would be of three general types to suit line size. The style and cost have been found to be as shown below:

Line Size	Style	Approx. Cost $ *	No. Required
Up to 150 mm (6")	Turbine type	1,650	6
Up to 200 mm (8")	In-line vortex type	3,300	8
Above 200 mm (8")	Insertion vortex shedding type	6,000	38

Each meter would feature direct dial reading, as well as have the capability of giving a remote signal at predetermined intervals, so that the reading can be totalized at the Freecool plant.

Control valves of the pneumatic type would be supplied, based on a 3 m WG pressure drop for the customer's estimated maximum flow. The valve would be controlled by a sensor located on the customer side. See Figure 22.

Billings would be based on total flow, but might include a maximum demand billing, as well, if future studies determine this to be desirable.

Although the estimates of energy revenues in the financial analysis are based on assumptions of energy use, it is important to note that invoicing would be based primarily on flow rather than energy. This would ensure that customers take steps to widen their range, thus preserving Freecool pumping capacity for future customers and reducing the pumping energy cost vis-a-vis total cooling or heating accomplished. This costing consideration would make Freecool income estimates conservative, since existing centralized water distribution systems have suffered chronically from inadequate range and overuse of water.

* Aggregate cost of all chilled and hot water meters is $400,000 approximately.

6.10 Water Outlet Spillway

Water returning from customers would arrive back at the pumping plant in the return segment of the supply/return conduit. It must then traverse a constant back pressure valve, which acts to keep the system full. After passing this valve, the flow would be diverted to a 3 x 4 m concrete box culvert, which would carry it to the harbour, adjacent to Captain John's restaurant ship. See Figure #16 This culvert would be submerged below the street and the low water line in the harbour. In order to reduce outlet velocity to 150 mm/s, the culvert would be doubled in area at the outfall, where there would be a trash screen to prevent the entry of large objects.

7.0 DESCRIPTION OF FREECOOL CONCEPT FOR HEATING

The heating function of Freecool, as noted before, is one which reclaims waste heat from the customers and elevates it to a useful (49° C) temperature for replacing the ventilation and perimeter heat losses of buildings.

Many recent and all new buildings use double glazing and can be heated with water at no more than 40°C. Even single glazed buildings like the Toronto-Dominion Centre can be heated with 49°C water. Those buildings which require up to 80°C water for maximum heating can use Freecool water at 49°C in moderate weather, although such buildings were excluded from this study.

Some complexes, such as Commerce Court and First Canadian Place, have heat reclaim cycles of their own. Yet, 75% of heating is required during unoccupied cycles when there is little heat to reclaim. Some buildings, such as Richmond-Adelaide Centre Phase II, the new Bell Canada Headquarters and Tower II of First Canadian Place, have thermal storage in addition to heat reclaim cycles. These buildings can reclaim most of the heat they need by flywheeling the daytime surplus toward nighttime use. The only advantage Freecool heating would have over such installations is the ability to operate its reclaim chillers entirely in the 11:00 p.m. to 7:00 a.m. valley proposed in the new 1982 Ontario Hydro time of day rates, see Figure 23.

7.1 Heating Concept

Studies indicate that, in the first year of system operation, heat from returning chilled water would furnish heating needs for days with an average temperature of approximately -1°C. Below this, steam would be purchased from the Toronto Hydro System at its standard rate schedule. Figure 24 illustrates this schedule in 1981. The heating recirculation circuit is indicated in Figure 25.

Above -1°C, the cooling storage tanks would overflow with returning water and there would always be a surplus of heat with which to load up the hot storage tanks between 11:00 p.m. and 7:00 a.m. The cooling circuit is illustrated in Figure 26.

On a day of perfect heat balance, in the year 1988, the heat loss and gain curves for the system would resemble those shown in Figures 27a, 27b and 27c.

7.2 Chiller Plant

In order to maintain the storage tanks as small as possible, the widest realistic water ranges would be used, 3 to 13°C for cooling and 32 to 49°C for heating.

Water as cold as 3°C can be generated with a simple series

flow arrangement of chillers, as shown in Figure 28. In the first pass, water would be cooled from 13°C to 8°C, while heating condenser water from 32 to 40.5°C. This could be accomplished in 1988 using 8 existing chillers, purchased from Freecool customers, with an aggregate capacity of 177 GJ/h (14,000 tons). In the second pass, two new chillers of equal aggregate capacity would boost the condensing water to 49°C and lower the chilled water to 30°C. The heat output of this cycle would be approximately 17.3 MJ/kWh, yielding a COP of 4.8.

In the year 1988, the chiller plant would be doubled, in order to accommodate the anticipated heating load of new construction arriving in the years 1988-2000.

The chiller plant would be sized to regenerate the maximum usable heat, which can be recaptured from chilled water, in the off-peak period of 8 hours between 11:00 p.m. and 7:00 a.m.

7.3 Storage Tanks

There would be three concrete storage tanks, each of 64,000 m^3 (17,000,000 USgal.) capacity, two used to store chilled water, most of which returns between 8:00 a.m. and 11:00 p.m., and one used to store hot water for all hours.

The tanks would be constructed at 16 m depth, as located on Figure 8. Approximately 6 m of the depth would be contained within shale rock. They would be equipped with a top and bottom nozzle matrix to maintain the stored and returning water temperature in a stratified condition. One cold tank would be piped to alternate as a hot tank, in case one tank needed to be drained for any reason.

The tanks would be sized to accommodate the maximum quantity of hot water which could be generated from returning chilled water.

The tanks would contain columns on typical centres, reinforced for future building loads. The lid of the tanks would be reinforced to return the parking lot to its former use.

7.4 Chiller Building

A building of 80 m x 30 m would be placed below grade, where shown in Figure 8. This building would be two storeys in height. The lower level would be used to arrange recirculation pumps and piping distribution to the chillers and supply/return pipe conduit.

A section of the upper floor would be provided for staff who would maintain the building full-time during the period the chillers are operating. The roof of the building would be reinforced for parking and/or a future above-grade building.

The upper floor would be 8 m in height, to arrange headroom for the largest chillers and for a travelling crane to service the chiller water boxes.

The building would be oversized for initial operation, in order to accept an additional chiller capacity of (354 GJ/hr) 28,000 tons in 1988 for the ultimate load.

7.5 Hot Water Supply Conduit and Branches

This would be run up Bay Street alongside the chilled water conduit. Its construction and take-off arrangements would be similar, except that the lining and partition would be made of insulating type concrete.

Conduit connections would be 450 mm in diameter, instead of 750 mm. Isolating valves in the building basements would be 300 mnm, in place of 600 mm, for chilled water. Branch lines would be of plastic construction and would parallel the routing of the chilled water lines.

The hot water conduit would be 2 m in diameter, to carry the ultimate flow of 3,200 l/s.

7.6 Heat Exchangers

The chilled water heat exchangers would be provided in at least several modules. In winter, when less cooling is required, some of the cooling modules would be valved for heating duty, as indicated on Figure 22. This arrangement provides an economy for customers since they would be required to buy heat exchanger modules in sufficient number only for maximum cooling.

Customers would provide the same input to division of cost as for the cooling pipe hook-up to the heat exchangers.

7.7 Unit Costing for Heat

Unit heating costs associated with various heating concepts, in 1981, are:

Central Steam	-	$7.54/GJ
On-site Heat Reclaim at Day Rate	-	$2.34/GJ*
75% Steam, 25% Heat Reclaim	-	$6.25/GJ
Freecool Heat Reclaim at Night Rate	-	$1.86/GJ**
On-site Heat Reclaim with Storage at Day Rate	-	$2.37/GJ***

* Based on 19.2 MJ/kWh, 250 hours/month, $4.25/kW demand, 2¢/kWh energy, Ontario Hydro charge in 1982 plus 25% mark-up for Toronto Hydro, less 10% escalation to 1981.

** Based on 17.4 MJ/kWh, 240 hours/month, $1.00/kW demand, 2¢/kWh, energy, Ontario Hydro charge in 1982 plus 10% for recirculation pumping cost, plus 25% Toronto mark-up, less 10% escalation to 1981.

*** Based on 19.2 MJ/kWh, 240 hours/month, $4.25/kW, 2¢/kWh, plus 25% mark-up, less 10% escalation to 1981. If the storage can be regenerated entirely within the 8 hour off-peak period, the unit cost would drop to $1.53/GJ.

From these data it is assumed that Freecool would attract heating loads from buildings which may have daytime heat reclaim, but have not seen fit to install storage. The cooling side of Freecool would still be attractive to customers using storage.

7.8 Heating Billing Concept

The intent is to sell Freecool heat based on the heat returned from the customers' chilled water heat exchangers. When a customer purchases more heat than he provided to Freecool from his use of chilled water, he would be charged at the low heat rate for the heat he provided and at the prevailing central steam rate for the balance. This is reasonable because, in cold weather, Freecool would have to import steam to maintain the required flow of 49°C water to the system. The lower charge for reclaimed heat would encourage customers to diminish their free cooling cycles in order to provide Freecool with as much heat, through returning chilled water, as they could use for heating.

7.9 Impact Upon Proposed Toronto Steam Grid

It has been proposed that some of Metro Toronto's waste be incinerated several miles west of the downtown core, adjacent to the Gardiner Expressway. Steam resulting from this incineration would replace the output from the present Toronto Hydro Pearl Street plant and, in addition, provide a base steam load for a steam grid that would link up the Queen's Park, Hospital and University of Toronto steam generating systems.

It has been assumed that the supply header linking the new plant with the Pearl Street network would pass alongside the proposed Freecool heating site and could be used for auxiliary steam to reinforce the reclaim concept.

Customers with heat reclaim systems have been second class insofar as steam generating systems are concerned, because they are poor customers during mild heating weather, while demanding almost 100% capacity on the coldest days.

This complaint can be levelled against Freecool as well, although Freecool, with its massive heat storage tank, has an offsetting bonus. While depreciating the seasonal load factor, it could actually improve the daily load factor by using storage to bank heat when the steam demand is low and to discharge heat for peak shaving during high demand. It is the second characteristic which affects steam plant sizing, the most essential factor in the price of incinerator steam.

Figure 29 depicts the steam delivery profile of the four major Toronto systems on a cold day. The two largest plants are based on metered profiles. The smaller ones are not well researched as yet, but the graph uses peak outputs derived from a 1975 report.

Figure 30 shows curve (1), the grid output, curve (2), the grid after deducting Freecool customers, and curve (3), the maximum after adding back the auxiliary steam requirement of Freecool on the coldest day. Note that, although Freecool includes customers not presently on any steam system, the maximum steam generation is less, by 100 GJ/h approximately, than if the situation remained unchanged. Factors which cause this are the effect of the reclaim cycle, which supplies up to 25% of required heat even on the coldest day, and the levelling impact of the storage on steam profiles.

Figure 31 is provided to indicate the possibility of even further levelling after heating retrofit is complete on the various buildings involved. The impact of energy conservation is to save heat by dropping out all equipment at night, but maintain the same 8:00 a.m. peak with a larger warm-up cycle. Curve (1) is the current requirement. Curve (2) would be the same without Freecool. Curve (3) is the same as (2), but after full energy retrofit. Curve (4) is the grid with Freecool added back in.

Note the drop in peak capacity now required at the incinerator plant. The overall saving by adding Freecool almost equals the contemplated first phase output of the proposed incinerator.

Steam would be used for back-up by feeding a bank of convertors located as indicated on the circuit diagram on Figure 25.

Freecool enjoys another element of compatibility with a refuse-fueled plant which can generate electricity with steam. Compare the net effect of heat in the building, if garbage is the base fuel. One ton of typical waste might provide 50% of its combusion heat, or 6 GJ, for useful input to the bulding*. The same ton of garbage could be burned to generate 600 kWh for use in the Freecool reclaim chillers. These, in turn, would provide almost 10 GJ to the buildings, based on an operating COP of 4.8.

Roughly a third of the 65 MW average electric generating capacity in the proposed refuse-fueled plant could operate the Freecool chillers. This energy would reclaim almost double the heat which could be derived directly from steam generated from the same amount of refuse.

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* This takes into account 25% loss in combustion efficiency, 20% loss, for lack of steam condensate return, and 10% line loss.

8.0 SUMMARY OF INITIAL COSTS

The purpose of this section is to state explicitly, the underlying capital cost assumptions on which subsequent financial evaluations are based. The sensitivity of overall results to changes in the assumed costs is examined subsequently.

Separate approximations have been made for the original cost of Freecool Cooling and Freecool Heating. These data have been derived, for heavy plant, from projections made by Proctor & Redfern - Supplementary Report #4.

The cost of pumps, new chillers, meters and control valves has been selected in discussion with manufacturers' agents. Piping and insulation costs nave been taken from current office pricing guides.

8.1 FREECOOL COOLING

Once installed, the system would have relatively low operating costs, but the start-up construction costs are significant.

Demand would be captured in two periods. The demand at the commencement of operations in 1987 would consist of buildings presently completed or in the process of construction. This start-up demand is expected to be complemented by additional customers, who are anticipated to join Freecool between 1988 and 2000. The system is sized from the outset to provide for this additional capacity, which equals 93% of initial requirements. The servicing of later customers thus requires only minor expenditures on pumps and branchlines.

The amount and timing of capital costs of the Freecool Cooling Project are developed in Figure 32 and summarized in Table 1. A brief description of these costs by categories used in the financial analysis model, is provided below. The model enables the 1981 dollar base value and escalation rates of any category to be independently altered.

8.1.1. Land

The major land and right of way requirements are:

8.1.1.1 Right of way on and beneath the lakebed of Lake Ontario for the intake tunnel.

8.1.1.2 700 m^2 of property (underground) for the central pumping station.

8.1.1.3 Right of way for supply and return conduit underneath Bay Street and through customer basements.

Provincial officials have advised that the lakebed and underlying lands are provincial Crown lands, administered by the Ministry of Natural Resources. The normal procedure for

TABLE 1

FREECOOL COOLING

CAPITAL COST SUMMARY
$'000,1981

Category	Year of Outflow	Amount System Cost	Amount Customer Cost	Amount Freecool Cost
		$	$	$
Land	1985	275	-	275
Initial Construction Value (including Fees and Contingencies)*	1983-1987	55,820	-	55,820
Heat Exchangers**	1986	16,826	16,826	
Chiller Rebate	1988	(1,055)	(1,055)	
Future Replacement on rebuilding of 71,000 tons of chillers,towers,pumps	2010***	(17,750)	(17,750)	
Pumps for Additional Capacity (including Fees)	1987	2,266		2,266
Branch Lines (including Fees)	1988-2000	3,542		3,542
Heat Exchanger vs. Chillers New Customers	1988-200	(16,817)	(16,817)	
TOTALS		43,107	(16,796)	61,903

* See Figure #32 for component costs

** Inclusive of associated pipes and fittings

*** This is a median date selected with the assumption of 30 years average life. Much of the equipment is already 10 years old.

use of "water lots", by lakeshore companies wishing to construct docking facilities or water intake/outlet systems, is to charge an annual leasing fee, equal to 10% of the "water lot" market value. In the case of a subsurface tract of land, 3 m in width and 6 km in length, the notion of "market value", has little meaning. Since pipeline charges are normally nominal, charges to Freecool would not likely be significant. Approval to construct the tunnel would, however, be required from numerous government agencies. These would include the Toronto Harbour Commission, Ministry of Natural Resources, Ministry of Environment, the International Joint Commission, the Federal Department of Transport, and probably others.

The Toronto Public Works Department confirmed that public utilities pay no right of way charges for lines traversing City managed properties. Apart from an initial application fee, there would be no charges for Freecool right of way underneath Bay Street. However, the approval of all other utilities with transmission properties in the vicinity (including Bell Canada, Consumers' Gas, City of Toronto and Toronto Hydro) would be required. In addition, the responsibility and cost of rerouting any other utility connections to enable Freecool installations, would be borne by Freecool.

The only significant land cost would be for the 700 m^2 of land required for the pumphouse building. Much of this building would be subsurface. Despite investigations, it was impossible at this time to determine a firm cost for land and rights of way. For the illustrative base case, an arbitrary amount of $275,000 was assumed. This reflects a belief that land and right of way costs, although real, do not represent a major capital cost to Freecool Cooling. The impact of land costs in excess of this amount can be determined from the Construction Overrun case in the sensitivity analysis reported on later.

8.1.2 Construction Value and Fees

The project would be tendered in 1985. The cash flows for construction value and fees used in the financial analysis are based on the 1981 quote, escalated at 10% per annum to 1985. Cash disbursements would be made as work is completed between 1985 and 1987. The present value 1981 dollar cost of construction is less than the value of the total cash ouflows indicated in Table 1. This is because of the discount applied to cash outlays in the second and third year of construction.

Inflation in construction to 1985 could be higher than the 10% rate assumed. The sensitivity of financial results to construction cost overruns, for whatever reason, are presented in a subsequent section.

8.1.3 Rebate for Chillers

Linkage to Freecool will eliminate the need for chillers on most customer premises. Only ten percent of chillers presently used for onsite heat reclaim operations, are likely to be retained by the customers. The balance of the 71,000 tons of chiller capacity will be sold for scrap in 1988 at an estimated value of $16.50/ton.

8.1.4 Future Replacement of Chillers

The cost of scrapping chillers and purchasing heat exchangers is a major expense. The customers would, however, be favoured with reduced costs in the future when replacing their cooling system. These savings amount to $160/ton. This has been treated as a capital cost saving for customers in the year 2010. The after-tax cost saving would be somewhat less, since there would be a corresponding reduction in the capital cost allowance claim for replacement equipment. This effect is captured in the financial analysis by showing a positive value for depreciation and a corresponding increase in taxable income.

8.1.5 Pumps for Additional Capacity

An estimated $2,266,000 would be spent in 1987 to provide sufficient pumping capacity for new customers being added to the system.

8.1.6 Branchlines

The installation of branchlines and related equipment to service cusotmers added in years 1988-2000 is estimated to cost $3,542,000. The actual timing of these expenditures would depend on the rate of increase in demand for Freecool Cooling. The base case assumes that future capacity would be realized in equal installments each year from 1988 to 2000. This involves a cash outflow to Freecool each year between 1988 and 2000 of $273,000.

8.1.7 Customers' Heat Exchangers

The customers should be persuaded to pay the cost of connection to the system. This would involve costs as follows:

		$ 1981
Purchase Heat Exchangers - 71,000 tons x $203.5/ton (incl. taxes)	=	14,449,000
Rig & Place Heat Exchangers - 250 units @ $1,100	=	275,000
Piping, valves and set meters and control valves - 26 installations @ $22,000	=	572,000
		15,296,000
10% Engineering Cost		1,530,000
		16,826,000

This outlay by customers would be repaid in part by the salvage value of chillers and in part by the Freecool rate schedule which would offer cooling and heating at a substantial discount over the status quo cost.

8.1.8 Heat Exchangers vs. Chillers

Later demands come from new buildings and, building additions, designed to operate with Freecool. By opting for Freecool, building owners save $253/ton of new water chilling equipment.

In the Base Case scenario, in the absence of Freecool, 5,115 tons of new water chilling equipment would be added each year from 1988 to 2000. This amounts to annual customer savings of $253/ton x 5,115 tons/year, or $1,294,000/year from 1988 to 2000. These savings are treated as a credit or cash inflow, to Freecool customers.

8.2 FREECOOL COOLING AND HEATING

Freecool Cooling and Heating costs are the sum of Freecool Cooling and Freecool Heating costs. These are developed in Figure 33 and summarized in Table 2. A brief description of cost categories not included in the Cooling project description is provided below.

8.2.1 Replacement of Worn Freecool Equipment

One of the features of the Freecool Heating and Cooling System is that it can use customer-owned chillers as part of its initial equipment at the Chilling Station. 15,000 tons of chiller capacity are purchased from customers (included in "Rebate for Chillers") in each of 1988 and 1989 at a cost of $55/ton.

TABLE 2

FREECOOL COOLING AND HEATING

CAPITAL COST SUMMARY

$'000,1981

Category	Year of Outflow	Amount System Cost $	Amount Customer Cost $	Amount Freecool Cost $
Land	1985	4,675		4,675
Initial Construction (including Fees and Contingencies)*	1983-1988	115,813		115,813
Heat Exchangers	1986	16,826	16,826	
Rebate for Chillers**	1988-1989	(2,211)	(2,211)	
Future replacement of chillers	2010	(17,750)	(17,750)	
Pumps for Additional Cooling Capacity including Fees	1987	2,266		2,266
Additions to Freecool Heating including Fees	1988-2000	7,205		7,205
Branchlines & Fees-Cooling	1988-2000	3,546		3,546
Branchlines & Fees-Heating	1989-2000	3,480		3,480
Heat Exchanges vs Chillers New Customers	1988-2000	(16,817)	(16,817)	
Replacement of Worn Freecool Equipment	2010	5,775		5,775
Saving on New Heating Plant	1989-2000	(8,250)	(8,250)	
TOTALS		114,558	(28,202)	142,760

* See Figure #33 for component costs

** 30,000 tons @ $55/ton = $1,650 (purchased by Freecool)
34,000 tons @ $16.50/ton = 561 (sold for scrap)
TOTAL = $2,211

The used chillers would have to be replaced in the year 2010 at a cost of $193/ton. Apart from annual maintenance expenses, there is no other provision for Freecool replacements of machinery and equipment. New equipment is expected to last the duration of the period considered for project evaluation purposes (i.e., 2030).

8.2.2 Savings in New Heating Plant

Later customers coming on stream between 1989-2001 will save approximately 2.50/m^2 on original heating equipment costs, by choosing the Freecool alternative. This amounts to customer cost avoidance of $688,000 in each of these years.

8.2.3 Additions to Freecool Heating

To provide later heating system capacity, expenditures are required in the amount of $7,205,000 in 1988.

8.2.4 Branch Lines and Fees - Heating

The installation of branch lines to service heating customers added in years 1989-2000 is estimated to cost $3,480,000. The actual timing of these expenditures would depend on the rate of increase in demand for Freecool Heating. The base case assumes that future additional capacity would be realized in equal installments each year from 1989-2000. This involves a cash outflow to Freecool each year between 1989-2000 of $290,000.

8.2.5 Land

Obtaining cost data for land was difficult for the same reasons as in the cooling case. In the absence of better data, a $4,400,000 cost of land for the heating system was used. This figure is based on consultation with City of Toronto Planning Commission authorities responsible for administering the proposed sites.

9.0 SUMMARY OF OPERATING COSTS

"Status quo" operating costs represent the costs that customers would pay in the absence of the Freecool Alternative. These costs are based on estimates of customer demands and projected energy prices from "status quo" sources (i.e., Toronto Hydro electricity and steam). These costs are compared later with Freecool costs to determine the overall annual operating savings offered by Freecool. Freecool revenues and customer savings are also derived from "status quo" cost data.

9.1 FREECOOL COOLING

The present energy requirements for cooling in the customer buildings were calculated using the profiles developed for the building load analysis. A chiller energy requirement of 0.80 kW/ton has been used in accordance with the typical operating requirement. To this must be added the energy for condensing water pumps and tower fans, resulting in a total of 1.00 kW/ton. Utility costing is based on the forecasted 1982 Ontario Hydro rates (Figure 23).

Pumping energy was estimated as described in Figure 19. Since the main water conduits are oversized for future, pumping losses are relatively small.

The results of the economic comparison are shown in Figure 34. Based on the proposed Toronto Hydro rate in 1982, cooling energy would cost as follows in 1981 $.

	Initial - 1987	Final - 2000
On-site Chillers (plus on-site auxiliaries)*	- $4,822,000	$9,304,000
Freecool Pumps	- 150,000	290,000
Energy Cost Saving for Freecool	- $4,672,000	$9,014,000

The operating cost includes such principal items as energy, staffing, maintenance, service contracts and chemicals, and administrative (office, legal, audit, etc.)

A comparison of operating costs is shown in Table 3.

9.1.1 Tax

If owned by the public sector, the utility would be subject to property taxes. If owned by the private sector, both income and property taxes will be levied.

* Including condensing water pump and water tower fan energy.

TABLE 3

FREECOOL COOLING OPERATING COST - $'000,1981

	Freecool	Status Quo
Initial Plant - 1987		
1. Electric Energy	150	4,822
2. Auxiliaries:		
Freecool staffing:		
5 - Sniftmen	100	
1 - Superintendent	28	
1 - Administrator	39	
1 - Clerk	15	
Customer staffing, say 15 men		330
Service Contracts	55	100
Repairs	25	50
Chemicals	28	275
Water make-up @ $1.50 M gal.	-	385
Clerical and Maintenance	100	-
3. Tariffs:		
Franchise Fees	74	-
Insurance	55	-
Property Tax	287	-
Sub-total	956	5,962

Additional Capacity by Year 2000*

	Freecool 1981 $	Status Quo 1981 $
1. Electricity	140	4,512
2. Auxiliaries	247	1,053
3. Tariffs	52	-
Sub-total	439	5,565
TOTAL	1,395	11,527

* In the years 1988-2000 costs increase annually by 1/13 of amounts shown.

9.1.1.1 Property Tax

Property tax treatment would be a key issue in determining ultimate Freecool economics and ownership options. As is indicated below, unless Freecool owners pay property tax at the rate applicable to municipal corporations (local or regional governments), the project economics are clearly unacceptable.

There are several issues involved in the determination of property and business tax. First, the elements of property which are subject to assessment are determined. The assessed value of this property would then be determined. Taxes are paid on the assessed value according to commercial mill rates in the municipality. In addition, utilities must pay business tax equal to 30% of property taxes.

Strict application of the Ontario Assessment Act would indicate that, unless owned by a municipal corporation, i.e., a local or regional government, all the structures, equipment and machinery of Freecool would be assessable. The market value of the property would be based on its "replacement" cost. Thus, the "market value" could be the entire $62 million capital cost of the project. According to discussions with Ministry of Revenue officials, the applicable assessment to market value ratio would be in the order of 25%, yielding an assessment of $15 million in round numbers.

At the current mill rate of $236.5 per $1,000 of assessment, this would result in property taxes of $2,960,000. Business tax would amount to an additional 30%, making total municipal taxes payable of $3,850,000, or about six times all other operating costs of Freecool.

Provincial or Federal Government operated utilities would pay the municipality an approximately equal sum of money in the form of a grant in lieu of taxes.

A utility owned and operated by a municipal corporation would only be assessed on land and buildings, since all machinery and equipment or "structures other than buildings, not considered to be an integral part of a building", are exempt. Assuming that the tunnel and distribution system are not considered an integral part of a building, a municipal corporation utility would be assessed only on the value of the central pump house and land. With an initial cost (market value) of $3,730,000 for pump house construction value and fees and land costs, exclusive of equipment, the property and business taxes for a municipally owned government utility would be $287,000 a year. This is the property tax amount included in the Base Case.

Property taxes in the order of $3.85 million for a non-municipal government utility, would offset 75% of available energy cost savings. The corresponding reduction in Freecool revenues would make the project economics unacceptable. For this reason, the base scenarios outlined in the subsequent section assume that Freecool is owned by local government. Since a public sector owner would pay no income tax, results of the base scenarios are shown on only a before tax basis. Other cases assume private ownership, but with property taxes at the same rate applicable to municipal corporations. (This would require significant tax concessions.) These latter cases evaluate returns on an after tax basis according to the tax treatments outlined below.

9.1.2 Income Tax

The returns to a private owner must be considered on an after-tax basis. Corporate means tax is assumed to be 50% of taxable income. Taxable income for the utility is approximately equal to net cash flow from operations less depreciation. The applicable depreciation rate is discussed below:

9.1.2.1 Slow Write-off

Freecool property would probably be considered "Class 2" assets, which include:

> "the distributing equipment, plant and structures of a distributor of water, the production and distributing equipment and plant of a distributor of heat."

Assets in this class are depreciated for tax purposes on a declining balance basis, with a Capital Cost Allowance (C.C.A.) rate of 6% a year. This is the depreciation rate allowed in the Base Case.

Note that only capital investments on lands owned or leased by Freecool can be claimed for capital cost allowance. This means that if Freecool has property on lands owned by someone else (a private land owner, or the City, etc.) a nominal lease fee should be charged so Freecool could include the "cost of leasehold improvements", in its capital cost base.

The Base Case also assumes that the Freecool Utility, if administered by the private sector, has other sources of taxable income which could make immediate use of tax write-offs, including maximum C.C.A. available. This means, for example, that during construction when Freecool has no income, tax savings on income from other business operations, amounting to 50% of the capital cost allowance, would be

realized. This tax saving is properly considered as a positive after tax cash flow to Freecool.

9.1.2.2 Fast Write-Off

Any cash inflows that Freecool could redirect from the long term to nearer the start up of operations, provide a significant bonus. One mechanism to achieve this is to write off Capital Cost at an accelerated rate. Freecool could seek a ruling to have its property considered as C.C.A. Class 34 instead of Class 2. The former class has a 50% C.C.A. rate. It includes property that is "production equipment and pipelines of a distributor of heat..." ("but not including buildings or other structures")...provided that the "property is part of a plan designed to:

9.1.2.2.1 Produce heat derived primarily from the consumption of wood or municipal wastes.

9.1.2.2.2 Product electrical energy by the utilization of fuel that is petroleum, natural gas or related hydrocarbons, coal, gas, coke, lignite or peat, wood wastes, or municipal wastes.

9.1.2.2.3 Recover industrial by-product heat.

C.C.A. Class 34 has a sunset provision which stipulates that the property must be acquired by the taxpayer before 1981. The 1981 limit is an extension from a previous limit, and it is anticipated that this limit may be rolled forward each year. The unique nature of Freecool prevents it from being specifically included in the description of the class, but it would perhaps be argued that the intention of Class 34 is to encourage energy conservation and the development of new energy technologies. If this is indeed the case, then the Department of Revenue might provide a favourable ruling permitting the inclusion of a significant portion of the Freecool Property in this fast write-off Class. The sensitivity case entitled "Tax Break", explores this alternative.

9.1.2.3 Research and Development

Since Freecool is the first application of a new technology, a portion of the capital costs could be considered to fall within the realm of research and development. Funds allocated to research and development can be expensed at 150% in the year they occur. At a minimum, the costs of engineering design and environmental studies would be eligible for this preferential treatment. This has not been investigated further.

9.1.2.4 The Importance of Tax Status

The possibilities of special income tax arrangements have been only briefly explored. This is clearly an area in which opportunities exist to alter project economics, and which should be firmed up as the project parameters become clearer.

9.1.3 Franchise Fees

As previously indicated, there would be no significant costs associated with rights of way for land under Lake Ontario.

The Ministry of Natural Resources has advised that a fee for the use of water could be levied. Although a special hearing would be required to determine the precise charges, the fees charged Ontario Hydro for hydro electric generation were cited as indicative of the sums involved. As with Freecool, there is no net water consumption by Hydro, since all water is returned. The rate charged Ontario Hydro is priced on an Energy basis and is tied to the Consumer Price Index. In 1981 the rate was $4.00/annual horsepower. If this rate applied to Freecool, annual charges for initial capacity would be $74,000, increasing by $4,000 a year through 1999, as additional capacity comes on stream. It is unlikely that additional fees for Freecool Heating would be levied since there is no change in the volumes of water drawn.

9.1.4 Insurance Costs

Four firms in the business of providing insurance for utilities and large-scale energy products were asked to estimate annual insurance premiums for Freecool. Estimates of insurance premiums for the operating system varied widely. For the purposes of a representative "Base Case", a figure of $55,000 is used. This would provide for property and boiler and machinery insurance, liability insurance, and business

interruption service. This latter premium provides protection against loss of utility income, but does not protect the utility from a customer suit for loss of business due to interrupted service.

It is understood that, at present, legislation prohibits customers from suing electric utilities for losses suffered as a consequence of blackouts or brownouts. Freecool could attempt to secure a similar waiver from its customers. The effect of the waiver on Freecool marketability and customer confidence would have to be traded off against the cost of insurance premiums offering similar protection. No broker would quantify the premium for this type of insurance, without first reviewing in detail the project engineering specifications.

All the costs quoted were based on "other utility" experience.

In the absence of details about the project, the inherent risks involved, and the coverage required, the brokers qualified their estimates, and cautioned that their figures were "ball park" estimates.

This is an issue which would require detailed investigation in subsequent studies.

9.2 FREECOOL COOLING AND HEATING

Almost 60% of Freecool heating would be provided by heat reclaim, the balance with purchased steam. See Figure 15.

9.2.1 Development of Freecool COP

The cost of Freecool reclaim is based on the operating COP of the chiller plant. In the series flow arrangement shown in Figure 28, the customer chillers are assumed to operate at 0.81 kW/ton* and the purchased second stage chillers at 1.02 kW/ton**. Since each stage does equal work, the average input will be $\frac{1.02 + 0.81}{2}$, or 0.92 kW/ton

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* Average catalogue data from Carrier and Trane. English units are used to correspond to the current state of manufacturer's literature.

** Derived by York Corp. for 7,000 ton units.

The COP may be derived as follows:

0.92 kWh transfers 12,000 BTU from chilled water to condenser water

Therefore 1.0 kWh transfers 13,043 BTU from chilled water to condenser water

Work heat adds 3,413 BTU to condenser water

Therefore 1 kWh transfers 16,456 BTU to condenser water

Therefore COP = $\frac{16,456}{3,413}$ = 4.82

9.2.2 Development of Freecool Operating Cost

The average cost of Toronto Hydro steam in 1981, including fuel escalation, was $7.54/1,000 lbs.

The cost of reclaim heating in 1981 was derived in Section 7.7 as $2.34/GJ.

The 1988 annual sale for heating from Figure 15 is 1,151,400 GJ.

The reclaim equivalent may be found, with reference to Figure 15, as follows:

477,000 GJ @ $7.54 or	$3,600,000
674,000 GJ @ $2.34 or	1,578,000

Plus estimates of electricity for pumping:

Chilled Water System Pumping	66,000
Hot Water System Pumping	74,000
Chilled and Hot Recirculation pumping	59,000
	$5,377,000

A comparison of operating costs for Freecool Cooling and Heating is shown in Table 4. This table illustrates the initial heating sale in 1988, together with the ultimate sale in 2000.

9.2.3 Insurance and Property Taxes

Insurance and property tax rates are identical to those outlined for the cooling system, but are applied to the appropriate combined values for the heating and cooling systems.

TABLE 4

SUMMARY OF OPERATING COSTS FOR FREECOOL COOLING AND HEATING

$'000/yr 1981

	Freecool	Status Quo
1. Freecool Heating - 1988		
i) Energy:		
Steam	3,600	8,681
Electric	1,777	-
ii) Auxiliaries:		
Staffing (add 5 persons to cooling staff. Operate pumping station by remote control)	110	-
Service Contracts	33	
Chemical	55	
Repairs	50	
Administration (shared with Freecool cooling)	75	
Maintenance		55
iii) Tariffs:		
Insurance	55	
Property Tax	704	
iv) Sub-total	6,459	8,736
2. Freecool Heating - 1989-2000*		
i) Energy:		
Steam	3,132	7,560
Electricity	1,265	-
ii) Auxiliaries:	283	43
iii) Tariffs:	-	-
iv) Sub-total	4,680	7,603
3. Freecool Heating Sub-total - 2000	11.139	16,339

* In the years 1989-2000 Freecool Heating Costs increase annually by 1/12 of value shown.

TABLE 4 (Cont'd)

SUMMARY OF OPERATING COSTS FOR FREECOOL AND HEATING

$'000/yr 1981

4. Summary of Freecool Cooling and Heating

	1988		2000	
	Freecool	Status Quo	Freecool	Status Quo
Freecool Heating	6,459	8,736	11,139	16,339
Freecool Cooling (Table 3)	956	5,962	1,395	11,527
Freecool Cooling and Heating	7,415	14,698	12,534	27,866

10.0 FINANCIAL EVALUATION

10.1 OVERVIEW OF FINANCIAL EVALUATION

This section analyzes the financial aspects of the Freecool concept from an investor viewpoint. The analysis is based on Net Present Values at varying discount rates, and internal rates of return. These are calculated for the Base Case cash flows outlined below, and for a set of plausible deviations from the base case assumptions. The base case is constructed with the middle scenario of three alternative energy price scenarios. Alternative scenarios were devised because of the uncertainty of long run energy prices, and the dependence of the financial results on energy price assumptions.

10.2 CASH FLOWS

The capital and operating cost data outlined in Sections 8.0 and 9.0 were used to generate cash flow projections, for the Freecool Cooling and Freecool Cooling and Heating projects.

10.2.1 Capital Costs

Capital Expenditures, by Freecool and customers are counted as cash outflows (or inflows in the case of customer cash avoidance) in the years they occur, in nominal dollars. Nominal dollars are estimated by inflating 1981 dollars at the rate of inflation, which in the Base Case is assumed to be 10%. For the item "construction value and fees", no adjustment to nominal dollars after 1985 is necessary, since the estimated 1985 tender value includes provision for cost escalation during construction.

10.2.2 Freecool Operating Costs

Operating costs for Freecool are shown as cash outflows, and increase in real terms during 1987-2000 to account for increments to initial operating levels. Nominal dollars are derived by applying inflation rates of 10% to auxiliaries and electricity, and a variable rate for steam. This has been calculated by Toronto Hydro to be at an average rate of 16%/year during the 1981-1986 period of governmental agreement. Beyond 1986, a baseline rate of 12-1/2%/year has been chosen in accordance with recommendations by Energy, Mines & Resources.

10.2.3 Status Quo Operating Costs

Operating costs for the "status quo" or existing on-site systems are treated as positive cash inflows, since these costs are displaced by Freecool. The base case rates of inflation for operating costs are the same as for Freecool.

10.2.4 Viewing Cash Flows from Various Perspectives

The system perspective shows the cash flows and returns generated if there is no allocation of costs and benefits between the customers and the utility. It represents the ultimate project returns that could be realized if rate structures could be devised to fairly allocate system costs and benefits between customers and utility operations, and should perhaps be the viewpoint taken by government decision-makers as they consider the overall merits of the project.

The revenues Freecool receives from customers were taken to be 80% of customer status quo costs. The precise rate structure whereby these revenues are generated does not affect the financial analysis.

The customer perspective examines the cash inflows and outflows of Freecool customers. Energy cost savings are a source of inflows and equal the difference between status quo costs and the charges levied by the Freecool utility. In the Base Case, it assumed that customers pay Freecool at 80% of status quo costs, resulting in savings to customers of 20% of status quo costs. Initial customers incur cash outflows to join Freecool while later customers actually receive cash credits representing savings in initial equipment costs. In the analysis, customers are treated as one group, and it assumed that appropriate pricing and rate structures would be formulated that fairly allocate benefits among initial and later customers.

The utility would incur capital and operating costs and receive revenues from Freecool customers. As described above, these revenues, in the Base Case, are assumed to be 80% of "status quo" energy costs. The 80% figure gives a margin of safety to Freecool revenue projections. It also results in the customers, in aggregate, receiving a much higher return on investment than the utility. Subsequent cases incorporate the impact of higher customer charges. If suitable rate-setting mechanisms could be developed, Freecool could recover a larger share of system revenues, particularly once the system was mature.

Tying Freecool revenues to existing prices results in the undesirable effect of earning low rates of return on investment during initial years, and higher rates during later years. Normally, utilities earn a regulated rate of return on invested capital on a year-by-year basis. This results in stable returns on investment over time.

In the case of Freecool, it has been assumed its revenues would be a function of alternative energy costs, since it must compete with utilities already in operation. A rate

based on capital invested, given the capital intensive nature of the project, would result in uncompetitive prices at the start, and very low prices (after capital assets are depreciated) at the end of the project.

10.2.5 Time Horizons

Cash flows are projected for each year of the project life. The "project life" is determined by investor time horizons, not by the lifetime of Freecool physical assets. Various project horizons are considered. There is no residual on scrap valuation applied to the asset at the end of the project.

Though in the base case, the utility is assumed to be owned by the public sector, financial returns are calculated both before tax and after tax. As is described earlier, the after-tax case assumes that the operator has sufficient taxable income each year from other sources to fully utilize the tax losses created by Freecool in its early years.

10.3 EVALUATION CRITERIA

10.3.1 Net Present Value

The Net Present Value captures the importance of the time value of money. All future net annual cash flows are discounted to present dollars and then summed. If this Net Present Value is positive, the project is an attractive investment. Crucial to this method is the selection of an appropriate discount or "hurdle" rate. The rate must at least equal the investor's cost of capital (appropriately weighted with debt and equity financing), but could be higher to reflect rates offered by other investment opportunities, or to compensate for relatively higher levels of project risk.

10.3.2 Internal Rate of Return

The internal rate of return is calculated from the cash flow pattern and represents the discount rate which yields a zero Net Present Value. This calculated internal rate of return is then compared with the investor's required rate of return ("hurdle rate"), in similar projects, to determine whether or not the project should be accepted.

10.3.3 Payback

Simple Payback is the number of years required to recover initial investments. There is no account of the time value of money or of cash flows beyond the payback period. The payback is calculated from the project start-up date, and corresponds to the year in which a zero internal rate of

return is earned (i.e., all cash outflows are recovered).

Discounted payback measures are similar to simple payback except that cash flows are discounted. The discount rate chosen could be the rate of inflation, the investor's cost of capital, or rates of return available on projects with similar risk. The corresponding payback periods represent respectively, the time required to recover the real or constant dollar value of initial investments, to earn a break-even rate of return, or to earn the rate of return offered by alternative investments. In each case, the payback year is the year in which the internal rate of return first reaches the discount rate specified.

The major shortcoming of payback criteria is that cash flows beyond the payback period are excluded. Payback measures are, however, appropriate for investors with short-time horizons, and are useful in assessing the relative risks of projects. Two projects with identical rates of return but different payback periods, would not be considered equal, because the investor requires a liquidity or risk premium from the project with the longer payback.

10.4 FINANCIAL ANALYSIS

10.4.1 Base Case Results

The results of the Base Case analysis are summarized below and shown in detail in Supplementary Reports 2 and 3. The analysis was performed from three perspectives, that of the total system, the customers, and the Freecool utility. The key assumptions of the base case are reiterated in Table 5. The energy price scenario for the base case is as determined after consultation with officials from Energy, Mines & Resources, Toronto Hydro, Consumers' Gas and CMHC. The assumptions underlying the base case have been chosen to be realistic. The base case results are therefore illustrative of returns which can be realized with a high degree of confidence.

The consideration of Freecool utility returns on a before-tax basis corresponds to a government operated utility, since no income taxes are paid. This is consistent with the assumption that the utility pays property tax at the favourable rate applied to municipal corporations. The results are summarized in Table 6.

Supplementary Reports 2 and 3 also show the after tax rate of returns applicable to private investors paying property tax at the municipal corporation rate.

It should be noted that at an after tax discount rate of 10%, the investment would generate no real rate of return in

excess of inflation. At a minimum, an investor requires a 3 to 5 percent real rate of return after taxes. Return on the equity portion of investment would probably have to be considerably higher.

The adequacy of returns on investment to Freecool are very much dependent on the time horizon adopted by the investor.

TABLE 5

ASSUMPTIONS FOR BASE CASE

- Freecool Revenues 80% of Status Quo Energy Costs
- All Later Demands Realized as Scheduled
- Public Ownership (non-taxable)
- Property Tax Only on Land and Buildings
- Construction and Operating Costs as Given
- Inflation in Steam price at 16% Per Annum 1981-86 and 12-1/2% Per Annum Thereafter
- Inflation in Electricity price at 10% Per Annum
- Inflation in All Other Categories at 10% Per Annum

TABLE 6

BASE CASE - RESULTS

(Before Tax)

COOLING - ONLY

	System			Customers			Freecool		
	2000	2015	2030	2000	2015	2030	2000	2015	2030
NPV at 15%* (Millions of $-1981)	11	62	86	11	26	32	0	36	54
IRR (%)	18	22	23	25	28	28	15	21	21
Simple Payback	6 years			4 years			7 years		

HEATING AND COOLING

NPV at 15% (Millions of $-1981)	20	144	225	44	91	119	(36)	53	106
IRR (%)	18	23	24	45	46	46	11	19	20
Simple Payback	6 years			2 years			8 years		

* The 15% refers to the discount rate used in the Calculation of Net Present Values (NPV). Net Present Values at alternative discount rates, and internal rates of return (IRR), before and after tax, are provided in the Appendices.

10.4.2 Alternative Energy Price Scenarios

The revenues received by Freecool are a function of the prices charged by competing energy systems. The base case, of a case representing a set of realistic but favourable assumptions, represents the most likely scenario with respect to future energy escalation rates. The high and low energy price scenarios show the sensitivity of project economics to future energy prices. The assumptions of these scenarios are detailed in Table 7. The corresponding results are shown in Table 8.

The scenarios illustrate the dependence of overall returns on changes in relative inflation rates. Though the cases examined did not result in more than +/-3% changes in real overall project return, such variations are significant to investors, particularly in view of the base case project rates of return.

10.4.3 Special Energy Price Scenario

At the time of printing this report there are potential costing scenarios for steam and electric energy which would affect Freecool economics favourably.

The assumptions for these changes are shown in Table 11 and the results are documented in Table 12.

10.5 SENSITIVITY ANALYSIS

Assessment has also been made of changes in base assumptions on overall project evaluation. Each change was made independently of other changes so that sensitivity of overall results to particular assumptions could be traced. The specification of sensitivity runs is shown below:

10.5.1 Sensitivity to Overall Inflation

These cases examine the dependence of rates of return on assumed rates of general inflation. The cases are outlined below:

	Inflation Rate (%)		
Case	Steam* after 1986	Electricity	All Other
Base	12-1/2	10	10
Low General Inflation	10-1/2	8	8
High General Inflation	14-1/2	12	12

*Before 1986 steam escalates at 16% in all cases.

10.5.2 Allocation of Status Quo Energy Costs

This case shows the effects of alternative splits of Freecool benefits between customers and the Freecool utility.

Case	Customers (Savings)	Freecool (Revenues)
Base	20%	80%
Lower Customer Share	10%	90%

TABLE 7

ASSUMPTIONS FOR ALTERNATIVE ENERGY PRICE SCENARIOS

1. High Energy Price Scenario:

   - Inflation in steam at 16% per annum - 1981-1986 and 15% per annum thereafter.
   - Inflation in electricity at 11.5% per annum.
   - All other Assumptions same as Base Case.

2. Low Energy Price Scenario:

   - Inflation in steam at 16% per annum - 1981-1986 and 10% per annum thereafter.
   - Inflation in electricity at 8.5% per annum.
   - All other assumptions, same as in Base Case.

TABLE 8

ALTERNATIVE ENERGY PRICE SCENARIOS - RESULTS

(IRR % Before Tax)

	System			Customers			Freecool		
Item	2000	2015	2030	2000	2105	2030	2000	2015	2030
COOLING ONLY									
High Energy Price	19	24	25	26	29	30	17	23	23
Base Energy Price	18	22	23	25	28	28	15	21	21
Low Energy Price	16	21	21	24	27	27	13	19	19
COOLING AND HEATING									
High Energy Price	20	25	26	47	48	48	14	21	23
Base Energy Price	18	23	24	45	46	46	11	19	20
Low Energy Price	15	20	21	43	44	44	8	16	17

10.5.3 Later System Demand Shortfall

This case assumes that later demands are exactly half of those estimated for the Base Case. All operating costs and discretionary capital costs are altered accordingly.

10.5.4 Construction Overrun

This case assumes that a 25% cost overrun occurs in construction. This test, though designed to represent variations in initial tender estimates, is also a valid test for other capital cost items (e.g., land or cost escalation) incurred prior to startup.

10.5.5 Tax Break

This case assumes that assets would belong to C.C.A. pool 34, allowing 50% per annum depreciation. Other cases assume assets belong to C.C.A. pool 2, allowing 6% per annum depreciation. The tax treatment is relevant only to private owners.

10.6 SENSITIVITY RESULTS

Summary results for each of the tested cases are presented in Table 9 and Table 10. No combinations of changes (such as low steam inflation plus construction overruns) were considered. In general, for moderate changes, deviations around the Base Case are additive.

In the cases examined, the long run (2030) rate of return for the Freecool Cooling "System" ranged between 21% and 25% before taxes. Rates of returns to the Freecool utility, based on charging customers 80% to 90% of status quo energy prices, ranged between 19% and 23%. In all cases, customer returns were more than satisfactory, ranging from 19% to 27% before taxes as early as 2000. Provision would have to be made to allocate total customer returns among initial and later customers.

The Freecool Cooling and Heating system proved less attractive than Freecool Cooling on an internal rate of return basis. Long run rates of return ranged from 20% to 25% before tax for the System and 17% to 22% for the Freecool utility.

The sensitivity analysis shows that the project economics do not hinge on the absolute levels of inflation assumed. In the low and high general inflation cases, nominal rates of return varied by the same amount (+/-2%) as the inflation rates, leaving real project returns unaltered. The real return on investment would remain the same, provided that the cost of debt varied with anticipated inflation. If the cost of debt was funded at a period of high inflation, the reduction in nominal rates of return would reduce the real return on equity. This level of financial risk is determined by the degree of leverage employed in initial financing.

TABLE 9

FREECOOL COOLING SENSITIVITY ANALYSIS

(IRR (%) Before Tax)

	System			Customers			Freecool		
	2000	2015	2030	2000	2015	2030	2000	2015	2030
Base	18	22	23	25	28	28	15	21	21
High General Inflation	19	24	25	27	30	30	17	23	23
Low General Inflation	16	20	21	24	26	26	13	19	19
Low Customer Share	18	22	23	19	23	23	17	22	23
Slow Demand Growth	16	21	21	24	27	27	13	19	19
Construction Overrun	15	20	21	25	28	28	12	18	19
Tax									
IRR (After Tax - No Tax Break)	12	17	18	N/A	N/A	N/A	8	15	17
IRR (After Tax - Tax Break)	15	20	20	N/A	N/A	N/A	12	18	19

TABLE 10

FREECOOL COOLING AND HEATING SENSITIVITY ANALYSIS

(IRR (%) Before Tax)

	System			Customers			Freecool		
	2000	2015	2030	2000	2015	2030	2000	2015	2030
Base	18	23	24	45	46	46	11	19	20
High General Inflation	20	25	26	47	48	48	13	21	22
Low General Inflation	15	21	21	43	44	44	9	17	18
Low Customer Share	18	23	24	34	36	36	15	21	22
Slow Demand Growth	17	22	23	44	45	45	10	18	19
Construction Overrun	15	21	22	45	46	46	9	17	18
Tax									
IRR (After Tax - Base)	9	16	17	N/A	N/A	N/A	2	12	13
IRR (After Tax - Tax Break)	14	20	21	N/A	N/A	N/A	9	16	18

TABLE 11

ASSUMPTIONS FOR SPECIAL ENERGY PRICE SCENARIO

1. Central Steam Cost

   There will be a surcharge of $2.00/m lbs. of steam, beginning in 1983, to defray the cost of plant cross connections.

2. Electricity Cost

   Increases for the years 1983-85 will be 14%, 16% and 14% respectively to cover the unprecedented high cost of borrowing.

3. All other assumptions, same as in Base Case.

TABLE 12

SPECIAL ENERGY PRICE - RESULTS

	Freecool Cooling		Freecool Cooling & Heating	
	Base Case	Special Case	Base Case	Special Case
SYSTEM (Before Tax)				
Net Present Value at 15% ($ million)	86	102	225	284
Internal Rate of Return (%)	23	24	24	25
Payback Period (years)	6	6	7	6
CUSTOMERS (Before Tax)				
Net Present Value at 15% ($ million)	32	35	120	139
Internal Rate of Return (%)	28	29	46	49
Payback Period (years)	4	4	2	2
FREECOOL (Before Tax)				
Net Present Value at 15% ($ million)	54	67	106	145
Internal Rate of Return (%)	21	23	20	21
Payback Period (years)	7	6	9	8

11.0 ADDITIONAL FACTORS TO CONSIDER

11.1 OTHER CONSIDERATIONS

Section 10.0 has provided a detailed financial assessment of the Freecool Project, based on a range of realistic assumptions regarding future conditions. An evaluation of the Freecool Project also requires a consideration of various other factors, which influence an assessment of the overall feasibility of the project.

In this Section, focus is on four such subjects. These are:

11.1.1 Pricing policies, and the ability to attract customers.

11.1.2 The implications of public utility status.

11.1.3 The availability of potential owner/operators.

11.1.4 Taxation status.

11.2 PRICING POLICIES

The viability of the Freecool Project would clearly depend on the ability of the owner/operator of the project to achieve almost complete market penetration in Downtown Toronto. The assumptions developed reflect virtually complete capture of those office buildings which are economical to service. In addition, they assume that most new construction in the service area would sign up with Freecool, once the system was in operation. One sensitivity case in Section 10.0 assesses the implication of a slower take-up of demands than is outlined in the Base Case.

11.2.1 Servicing Customers

A number of preliminary discussions have been held with potential customers of Freecool. In these discussions, potential customers stated that they would require rapid paybacks of the sum capital costs, to induce them to participate in the Project. The revenue sharing assumptions in the financial analysis reflect this rapid payback.

In addition to the payback of capital investment by the customers, it is reasonable to assume that, in exchange for trading a familiar energy supplier for an unfamiliar source of cooling water, customers would require some concessionary pricing. It has been assumed that this would take the form of a discount from full energy cost recovery, in the rate structure of Freecool.

Within this framework, the development of a specific rate structure could be complex. In particular, it would be necessary to equitably treat both initial and later

customers, although the financial implications to these two classes of customers of signing up with Freecool vary considerably.

No attempt has been made to devise a potential rate structure for the utility, either from the point of view of market acceptance, or from the point of view of regulation. This second subject is discussed below.

11.3 PUBLIC UTILITY STATUS

Another practical consideration to be considered in an assessment of the Freecool Project, is whether the project would have public utility status. This subject has not been investigated in detail, nor has legal opinion been sought. It appears, however, that there is a good possibility that the Project would operate as a Public Utility, subject to both "The Public Utilities Act" and "The Municipal Franchises Act".

Such an assumption was made when Freecool was described as "a utility" earlier in this report.

11.3.1 Typical Regulation of Utilities

One practical consequence of this is that the pricing system being proposed for Freecool is not compatible with the current methods generally used to regulate public utilities. In Ontario, virtually all utilities are regulated on a return to rate base, with rates set in each year to cover that year's costs, plus an appropriate return to capital.

This approach is inconsistent with the pricing assumptions which have been utilized in this study. During discussions with informed people in Ontario, it became clear that this problem has emerged with other innovative energy-saving utilities, but has not yet been resolved. Such resolution would be required before it would be appropriate to commit to the Freecool Project.

11.4 AVAILABILITY OF OPERATORS

For a number of reasons, it is likely that an established business or agency will be required to operate Freecool. The basic rationale includes:

11.4.1 The financing of the project is likely to require the credit strength of an established organization.

11.4.2 If the system is to be operated by a private sector owner, there are tax advantages to having an existing stream of taxable income, which can be sheltered by Freecool losses in early years.

11.4.3 The administrative and organizational support for the Freecool Utility would probably be more economically provided within the framework of an existing organization.

Preliminary exploratory discussions have been held with a limited number of potential operators of Freecool. The results of these discussions are essentially inconclusive. To some extent, the time horizon required to obtain a reasonable return on investment in Freecool exceeds the planning frameworks adopted by many organizations. In addition, an impression was gained that the project is still sufficiently speculative that it is difficult to obtain clear expressions of interest from particular participants. It is anticipated that, as the parameters of the project are made more specific, expressions of interest would also become clearer.

11.5 TAX STATUS

Freecool is an innovative project, and has few precedents in Canada. For this reason, it is difficult to get a definitive view of the potential tax position of the Utility, from the perspective of both property tax and corporate income tax.

As outlined earlier in this study, the potential property tax liability of Freecool could be high. It is anticipated that there is probably significant room for negotiating property taxes downward. This would clearly be a priority task.

Similarly, the appropriate capital cost allowance treatment of Freecool is not yet clear. There is the potential that the property of the project could be written off quite quickly, for tax purposes. This would have a reasonably significant impact on overall project economics. Again, this is an issue which would require further resolution.

It is in the nature of such projects, that this uncertainty with respect to the tax position of the project exists in the preliminary feasibility stages of the project. It is anticipated, in the natural course of events, that these uncertainties would be reduced through discussion and negotiation, as the project is delineated more clearly.

12.0 ITEMS REQUIRING FURTHER STUDY

It is hoped that the financial and energy conservation aspects of Freecool, together with the unique location of Toronto with respect to implementation of such a project, will, together, justify further study.

A complete concept study which is competent to resolve engineering, financial and jurisdictional aspects and verify capital estimates, may cost 1% of the projected project cost. Since this is a large sum, it will be necessary to review the areas of uncertainty and rank them in relation to their cost and their impact on the overall Freecool potential.

The following is a list of concerns which is priorized, to include those items, first, which are critical but low in cost of review and, last, those items which are less critical but expensive to carry out:

	Task	Category	Remarks
12.1	Identify potential owner/operators of Freecool	Marketing	It seems logical that further examination of Freecool should await a strong expression of interest on the part of a potential operator. In the public sector, potential candidates would include the City of Toronto, who already intend to distribute steam, Metro Toronto, the Province of Ontario, Toronto Hydro and Ontario Hydro. In the private sector, the most likely candidates would be energy companies who have heavy profits to cover the initial investment of Freecool and wish to adopt the strong conservation image which Freecool would provide. Chief prospects would be oil and gas companies. This report should provide enough documentation to test reactions and see if support can be found.
12.2	Cooperation with Affected Authorities	Jurisdictional and Marketing	Time should be allocated to contact groups who might become involved and and to determine who should be contacted and what their interests and objections might be. Dialogue from that point should be aimed at

Task		Category	Remarks
			keeping them informed and resolving their differences. Already, the Freecool Response Group includes the nine organizations mentioned earlier in this report. As well, contact has been made with Metro Toronto over Toronto Island sites and with the Ontario Ministry of the Environment over ecological considerations. Other potentially interested parties, who have not yet been contacted, include Consumers' Gas and Bell Canada, for rights of way, the Ontario Ministry of Natural Resources, the Federal Department of the Environment, the Federal Department of Transport and the International Joint Commission.
12.3	Clarify the Property Tax Situation for Freecool	Financial	As noted earlier, property tax, taken at its severest definition, would consume 75% of Freecool savings. A definition of intent must be secured from the Ontario Ministry of Revenue and lobbying done, if necessary, to see that such a penalty can be avoided.
12.4	Clarify the Income Tax Situation for Freecool	Financial	The Federal Department of Revenue must be consulted to define such matters as the category of Capital Cost Allowance for Freecool. Other rulings should be sought to see how much of the initial cost of engineering can be written off as research and development expense. Input from the Department is also required in order to design a rate structure. Will Freecool be regarded as a utility and, if so, how can the heavy front end cost be sold to the customers? Several rate scenarios need to be conceived before these meetings are held.

	Task	Category	Remarks
12.5	Review Intake Routing and Building Sites	Jurisdictional Engineering Financial	The above mentioned meetings with jurisdictions will have a great deal to do with the selection of sites for the Freecool pumping station, chiller plant and storage tanks. There is a current aesthetics problem with the pump house since it requires a surge volume, 10 m above grade, to accommodate the 50,000 tonnes of water in the intake, which may be moving at a speed of 2 m/sec when power fails at the pumps. Pump location is interactive with other cost and engineering factors, so this is one of the first design matters to be settled. The location of the chiller plant and storage, which can be underground, totally, is also a significant cost variable.
12.6	Assess Environmental Considerations	Jurisdictional Financial	The attitude of the Ontario Ministry of the Environment is that the Freecool Study Group must determine what factors may impact on the ecology of Toronto and Lake Ontario, and then write a report to prove that these factors are favourable, or at least benign. As noted earlier, this report may cost $150,000, so some way should be sought to carry out the examination in stages, with Stage #1 used to establish a 90% certainty of approval.
12.7	Investigate Code Requirements	Jurisdictional Financial	Despite the fact that the PVC piping contemplated for Freecool will be in sub-basements and full of water, it is still considered a fire hazard by the City of Toronto. Asbestos insulation may overcome this problem, but the sleeving through party walls must be approved for a 2 hour rating. A list of similar code problems should be made and meetings arranged with officials to find cost effective solutions.

Task		Category	Remarks
12.8	Review Potential for Subsidies	Jurisdictional Financial	The Federal Government has subsidized activities related to energy in the past. Although these subsidies have been major for finding energy and minor for saving it, there is a shift in thinking toward "repairing the leaky bucket, instead of drilling the well deeper". Our senior government might be more enamoured with Freecool if it were seen to be a repeatable technology. Unfortunantely, there are few places in the world where a large collection of chillers lies alongside a body of 4°C water. Preliminary investigations of Winnipeg and Calgary with well water and Vancouver with bay water reveal, at least, a good chance of viable free cooling. These sites require investigation to the level of this report.
12.9	Validation of 4°C in Lake Ontario	Engineering	The cost of placing the intake at 100 m in depth in place of 80 m, as proposed, is a larger and longer, by 2 km, intake, worth a premium of $25,000,000. It is therefore very important to know, not only that the 4°C temperature is assured, but that intake swirl patterns do not bring in warmer water from a higher level. The study and model testing necessary to verify the present assumptions has been estimated by Farrell Boyce of the National Water Institute to cost approximately $50,000.
12.10	Assessment of Customer Cooling and Loads	Engineering	Assuming that a rate schedule has been designed to make Freecool an attractive alternative to Heating mechanical cooling and central steam, absolute assurance must be gained concerning the cooling and heating loads which would be impressed on the system. This would require an analysis of existing cooling and heating use for every potential customer. Exclusions would be made for heating energy, such as reheat, which the customer

Task	Category	Remarks
		intends to eliminate with system modifications. The loads research would be interactive with the customer, so that he would have no difficulty in cosigning the estimate. The customer would also be asked the conditions under which he would agree to join the system. This question would require a written statement by a senior officer of the company.
12.11 Customer Detailing	Engineering	A survey of each potential customer will be required to ensure that he has the basement space to locate heat exchangers prior to removing his chillers. Further time would be necessary to locate the most logical routes for branch piping and the appropriate connection points to the main supply/return conduits.
12.12 Water Temperature and Range Survey	Engineering	Pumping energy can be saved and pipe sizes reduced if the Freecool temperature range for cooling and heating is widened. Engineering time is necessary during the loads survey to find the optimum initial temperature and widest practical range for each customer. This will enable a reasonable selection of pumps and conduits for engineering concept and cost estimate. The Δ T for cooling and heating may vary up or down from values assumed in this report. A sideline to this study will be the accurate estimation of temperature loss and gain in the system piping as a whole.
12.13 Fringe Customer	Engineering	Only major customers were considered for Freecool. Up to 20% more capacity may be available initially if smaller buildings are approached. An effort should be made in the next stage of design to establish the smallest practical size of customer and to see that all who can qualify for connection are included in the survey.

Task	Category	Remarks
12.14 Prepare Concept Design	Engineering	With the above information available, a careful concept design can be prepared to optimize energy and realize the best return on investment. This would be prepared during the sketch plan stage, suitable for accurate costing.
12.15 Prepare Estimates	Engineering	Estimates must be prepared in detail on the basis of the concept design, for the benefit of the potential system operators, who were revealed earlier. This must be carried out carefully, with the help of contractors specializing in the work.
12.16 Prepare Final Financial Presentation	Financial	The instruments of financial measurement used in this report should be reapplied to the final estimates to verify the IRR assumed from the outset. In addition, a more detailed financial analysis should be conducted with attention to: - project timing - institutional organization - financial and balance sheet structure.

13.0 FAVOURABLE OPPORTUNITIES FOR FREECOOL WHICH REQUIRE FURTHER EVALUATION

Freecool has been conceived as an engineering opportunity.

An operator with entrepreneurial flair might see greater opportunity in a concept which conserves vital energy resources, reduces energy costs, lowers air pollution and, in time, can turn a good profit.

Some of the possibilities which have not been considered, as yet, but which could improve Freecool prospects, are listed below:

13.1 Non-Waterfront Land

Excavation material from intakes and storage tanks could be barged to the Leslie spit as planned. But, if approval were received, it could be used, alternatively, to generate 4 hectares of new waterfront land. With condominium zoning, this could create a real estate asset of some $50,000,000.

13.2 Subsidies

Government subsidizes the finding of new non-renewable energy. Freecool is renewable. It can lay the same "golden egg" year after year, for centuries. Perhaps, if the case were presented in the context of oil which doesn't have to be found, Freecool could earn the taxpayer's favour in the form of construction grants.

13.3 Larger Customer Pool

Freecool economics improve with the density of cooling demand. This can be increased by 15% or so by including the smaller buildings which may lobby to join the system. This fringe group has yet to be investigated seriously. In subsequent studies, Freecool profits may be assisted with this supplement.

13.4 Larger Heating Sale

Efforts to estimate the potential sale of reclaimed heat have not included reheat for temperature control. It has been assumed that this parasitic form of energy will eventually be eliminated in downtown Toronto buildings. A more likely event is that it may be reduced, but not below a level equal to 25% of the current estimate of heating sale.

In the first year of operation, the sale of heat for this purpose may augment annual income by some value between two and three million dollars.

13.5 Demand Sensitive Hydro Rate

The Toronto Hydro rate may retain its present electric demand sensitivity instead of changing to reflect the proposed new Ontario Hydro rates. This could boost Freecool cooling income by approximately $2,000,000/year in 1987.

13.6 Freecool Cooling Extension

On the hottest day, the Freecool plant will be pushed to its pumping limit* to serve the system. However, this is only a 10 hour peak. Over 24 hours, the plant will never use more than 60% of its lakewater pumping capacity.

If future customers were to install holding tanks, they would spend less than for comparable mechanical cooling. They would then be in position to fill their storage at night for cooling their building on the following day with nighttime spare Freecool pumping capacity.

This concept could be promoted to extend Freecool cooling income by up to 65%.

13.7 Ice vs. Water Storage

Heat can be stored more compactly in ice than in water. Preliminary studies have indicated that the 128,000 m of volume required for chilled water storage could be reduced to 24,000 m (6,000,000 USgals.), if ice were used instead. The saving in land cost and tank construction would net out to approximately $3,000,000 after making allowance for additional hardware for ice formation and harvesting. The premium cost of energy for making ice over chilling water would be about $250,000/year, not enough to destroy the attractiveness of the saving. This could be investigated further.

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* The intake tunnel is sized for a 7 m draw-down at the pump house. By extending this to the ultimate of 8 m, 10% more capacity could be used.

14.0 CONCLUSIONS

14.1 Validation of Study

The financial aspects of the cooling and heating side of Freecool have been evaluated on the basis of the preliminary studies carried out for this report. The results, as proposed, indicate that both concepts are viable, technically sound and worthy of further study.

14.2 Financial Aspects of Cooling and Heating

In addition to favourable financial considerations, Freecool would provide energy conservation, both in electricity for cooling and natural gas for generating steam.

The lakewater pumps would require only 5% of the electric energy currently used by electric chillers, whose function they would replace. This saving, by the year 2000, would amount to 120 MW(demand) and 235,000 MWh (consumption) each year. Cost avoidance for this energy would be approximately $9,000,000, as derived in Figure #34.

The heating energy which could be accomplished through heat reclaim is 1,260,000 GJ (see Figure 15). This is over 50% of the building requirements. As derived in Section 7.7 the Freecool cost of energy is $1.86/GJ compared with central steam at $7.54/GJ. The cost avoidance for this price differential in heating energy is approximately $7,100,000.00.

14.3 Capital Cost of Freecool

The estimated capital cost of Freecool is $62,000,000 for the cooling function or $142,000,000 for the combined heating and cooling functions. However, the Freecool customers would benefit from a net reduction in capital expenditures for building systems. This reduction in expenditures is estimated to be $19,000,000 for the cooling function and $28,000,000 for the combined heating and cooling functions. Major reductions of cost, to the customers, result from eliminating the need of future replacement of chillers in existing buildings and purchasing chillers and heating systems for new buildings.

A major cost for the cooling function of Freecool would be the cost of the 6 km long intake tunnel under Lake Ontario. This length is required to achieve a depth of 80 m in order to be assured of 4^{o} C water. See Figure #7.

A major cost for the heating side of Freecool would be the construction and assembly of tanks, chillers and pumps at a suitable central location.

14.4 Financial Summary

A financial analysis for the base case was performed, based on the

financial assumptions listed in Table 5 Section 9. The analysis was performed to examine the financial returns from three perspectives:

- Total system (of interest to government)
- Customers
- Freecool utility (of interest to a potential Owner/Operator)

The project is characterized by long payback periods. Rates of return are low until the year 2000, rise to the year 2015 and stabilize thereafter.

For the base case, the internal rate of return and simple payback period can be shown as follows:

Internal Rate of Return (IRR)%

	System		Customers		Freecool	
Year	Cooling Only	Heating &Cooling	Cooling Only	Heating &Cooling	Cooling Only	Heating &Cooling
2000	18	18	25	45	15	11
2015	22	23	28	46	21	17
2030	23	24	28	46	21	20

Simple Payback Period

6 yrs.	6 yrs.	4 yrs.	2 yrs.	7 yrs.	8 yrs.

14.5 Sensitivity Analysis

A sensitivity analysis was performed to review the impact of varying assumptions, both favourable and unfavourable. These include rates of inflation and energy escalation, the impact of taxes, cost overrun and the potential of reduced sale. These studies indicate that, for reasonable changes in baseline assumptions, nominal rates of return vary only moderately.

14.6 Reuse of Customer's Chillers

Eight of the largest discarded chillers from the Freecool cooling customers would be reused in the Freecool heating program. The balance could be sold at auction. The resale of chillers would subsidize the purchase of heat exchangers.

14.7 Avoidance of Traffic Interruptions

Traffic interruptions, commonly associated with the installation of central plant services, could be avoided to a large extent. This would be accomplished, for Freecool, by supplying water through concrete lined tunnels bored in the rock below Bay Street and, by

using the mutually connected basements of customers.

14.8 Land Requirements

The land requirements for Freecool are modest. For the cooling function a 36 m diameter pumphouse is all that is required. This could be located on ground provided by the Toronto Harbour Commission, on Toronto Island or Freecool Island, land created by Freecool tunnelling residue. For the heating function, approximately one hectare of subterranean ground for storage tank and chiller plant, as close to Bay Street as possible, would be necessary. At present, a site owned by the City of Toronto at the foot of Bay Street may be available.

14.9 Compatability with Existing Central Steam System

The storage element involved with the Freecool heating concept would be very compatible with the existing central steam network. For reasons of energy conservation, many downtown buildings would eventually use little steam except for a major warm up cycle between 6 a.m. and 8 a.m. The supplementary steam required by Freecool could be fed into storage to avoid adding to the peak steam surge required at this time. This would help to reduce investment in future steam generation facilities.

14.10 Financial Viability

The payout period for Freecool investment lies within 10 years and the rate of return in the base case exceeds 20 percent. These ratios should provide a stronger financial incentive than found with many energy conserving concepts of this magnitude.

14.11 Renewable Energy Sources

The energy sources for Freecool cooling and heating are freely available from lakewater and customer waste heat and are renewable year by year.

15.0 RECOMMENDATIONS

As a result of this technical and financial analysis, it is recommended that funding be obtained to carry out the following work:-

15.1 Sponsorship Opportunities

Review the opportunities for sponsorship of Freecool by four levels of government - Federal, Provincial, Metropolitan and City. This will require active solicitation of interest among those persons most directly involved at each level.

15.2 Solicit Potential Owners/Operators

Determine interest in Freecool among potential Owners/Operators including the City of Toronto, existing utilities and private corporations in the energy sector who could benefit from the capital cost allowances afforded by Freecool.

15.3 Inform Potential Customers

Circulate copies of this Freecool Study among potential customers who were approached initially for information. Arrange a group meeting, for representatives of these customers. This would provide a forum for assessing future problems and present level of support.

15.4 Review Jurisdictions

Meet with the appropriate governmental officials to discuss regulations related to capital cost allowances, property and business tax and the value of licences to use Lake Ontario water and the necessary right of way under streets.

15.5 Examine Potential Sites

Meet with City of Toronto Planning Department for discussions regarding equipment sites and the possibility of providing new harbour front land with Freecool fill.

15.6 Update Report

Assemble information derived from marketing and taxation discussions and prepare a report outlining further technical and financial investigations of Freecool which should be undertaken.

15.7 Secure Funding

If taxation barriers can be modified in keeping with the conservation aspects of the project, funding should be secured from a potential Owner/Operator and as many levels of government as possible to complete the further conceptual examination of Freecool as outlined in Section 12.0.

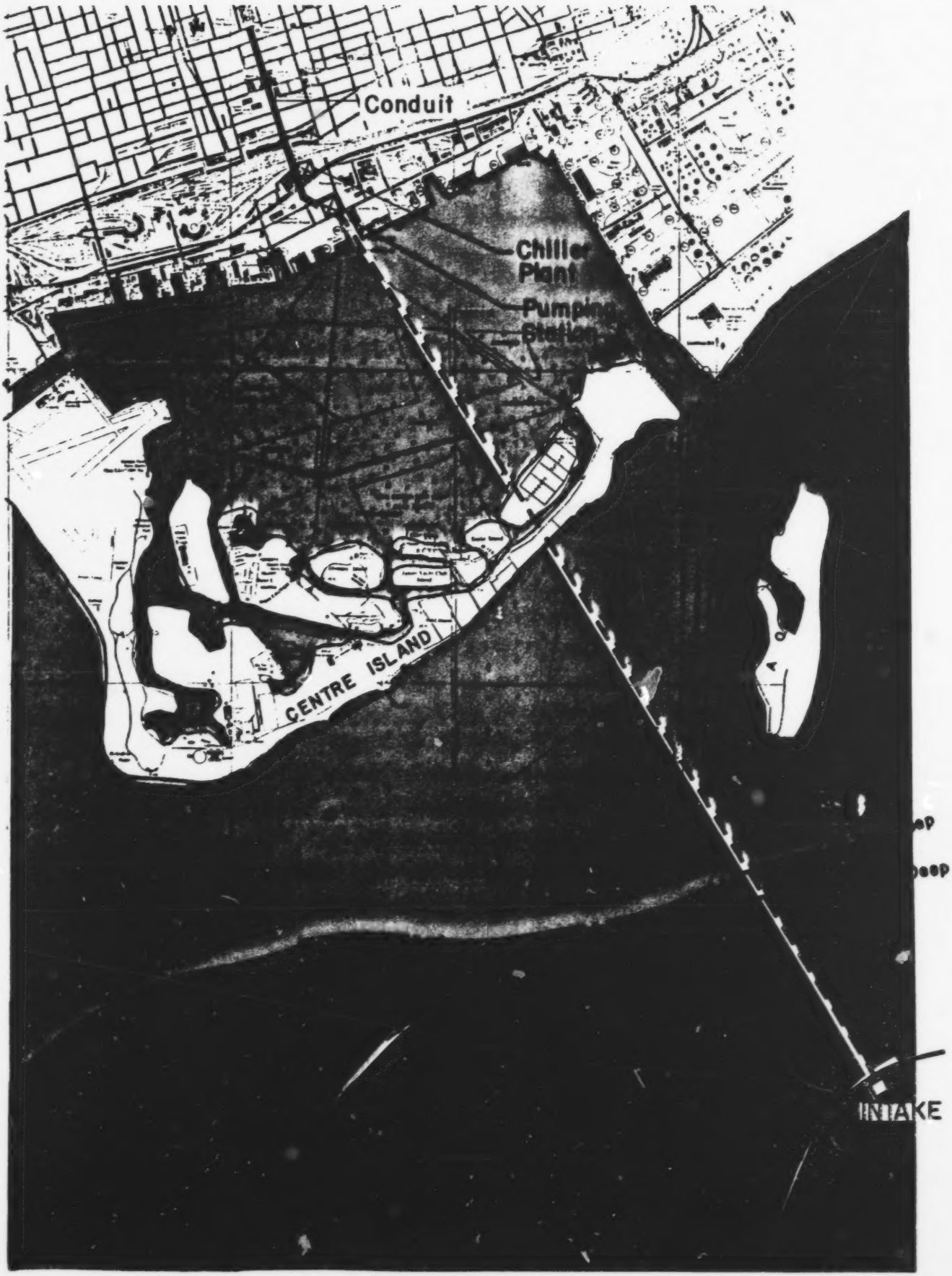

Conduit
Chiller Plant
Pumping Station
CENTRE ISLAND
INTAKE

Fig 1

SUMMARY OF COOLING LOADS
Available in 1987

Name of Building	Location of Chillers: Bottomside (Available to Freecool) MJ/Hr.	Location of Chillers: Topside (Not readily available to Freecool) MJ/Hr.	Maximum Cooling Available to Freecool: Cooling MJ/Hr.	Maximum Cooling Available to Freecool: Litres/Sec. Water @ 7.2°C ΔT	Remarks
Group A - Existing Buildings					
55 University Avenue	6,330		6,330	58	
111 Richmond St. W.		1,901	0	0	
390 Bay Street		13,928	0	0	
Bank of Nova Scotia	11,400		11,400	105	
Canada Permanent Bldg.	11,400		11,400	105	
City Hall	23,923		23,923	220	
Commerce Court	58,252	50,655	88,642	814	See Note 1
Commercial Union Bldg.		24,136	24,136	222	Full size water pipe to basement
Eaton Centre	30,390		30,390	279	
Eaton Tower I	15,195		15,195	140	
First Canadian Place Tower I	51,922	50,655	83,580	767	See Note 1
First Canadian Place Tower II	15,195		15,195	140	

Fig. 2

SUMMARY OF COOLING LOADS
Available in 1987

Name of Building	Location of Chillers: Bottomside (Available to Freecool) MJ/Hr.	Location of Chillers: Topside (Not readily available to Freecool) MJ/Hr.	Maximum Cooling Available to Freecool: Cooling MJ/Hr.	Maximum Cooling Available to Freecool: Litres/Sec. Water @ 7.2 °C ΔT	Remarks
Guardian Life	11,400		11,400	105	
Harbour Castle Hotel/Convention Centre	16,462		16,462	151	
Harbourside Condominiums	12,667		12,667	116	
Hotel Toronto		4,432	0	0	
Richmond/Adelaide Centre I		17,096	0	0	
Richmond/Adelaide Centre II	18,997		18,997	174	
Royal Bank Plaza		37,991	0	0	
Royal Trust Tower		49,362	49,362	453	Full size water pipe to basement.
Royal York Hotel	20,265		20,265	186	
Sheraton Centre	37,995		37,995	349	

SUMMARY OF COOLING LOADS
Available in 1987

Name of Building	Location of Chillers: Bottomside (Available to Freecool) MJ/Hr.	Location of Chillers: Topside (Not readily available to Freecool) MJ/Hr.	Maximum Cooling Available to Freecool: Cooling MJ/Hr.	Maximum Cooling Available to Freecool: Litres/Sec. Water @ 7.2 °C ΔT	Remarks
Simpson's Store and Tower	40,522		40,522	372	
Thompson Building		6,964	0	0	
Toronto-Dominion Bank		65,814	65,814	604	Full size water pipe to basement
York Centre		23,405	0	0	
Group B - Buildings Under Construction					
Bell Trinity Square	29,493		29,493	271	
Eaton's Tower II	7,598		7,598	70	
Oxrap	10,132		10,132	93	
Sun Life - Tower I	15,195		15,195	140	
Group C - Buildings Proposed for 1986 Occupancy					
Bay-Yonge-King-Adelaide Addition	37,995		37,995	349	
Fidinam	31,657		31,657	291	
Miscellaneous	31,657		31,657	291	
Harbourfront	126,637		126,637	1,163	

Fig. 2

SUMMARY OF COOLING LOADS
Available in 1987

Name of Building	Location of Chillers: Bottomside (Available to Freecool) MJ/Hr.	Location of Chillers: Topside (Not readily available to Freecool) MJ/Hr.	Maximum Cooling Available to Freecool: Cooling MJ/Hr.	Maximum Cooling Available to Freecool: Litres/Sec. Water @ 7.2 °C ΔT	Remarks
Sun Life - Tower II	18,997		18,997	174	
Harbourside Condominiums	6,330		6,330	58	
Total Load	698,006	346,339	899,366	8,260	
			(71,000 tons)		

Note 1 - These buildings have topside chillers serving the upper levels. They can be connected to Freecool, however, by using the discarded condensing water lines for the bottomside chillers.

Note 2 - An additional 898,860 MJ (66,000 tons) of cooling is expected to be added to the system in the period 1987-2000.

Note 3 - These building have a full size chilled water pipe to the basement

CROSS SECTION
Lake Ontario Thermoclines
July 5–7, 1972

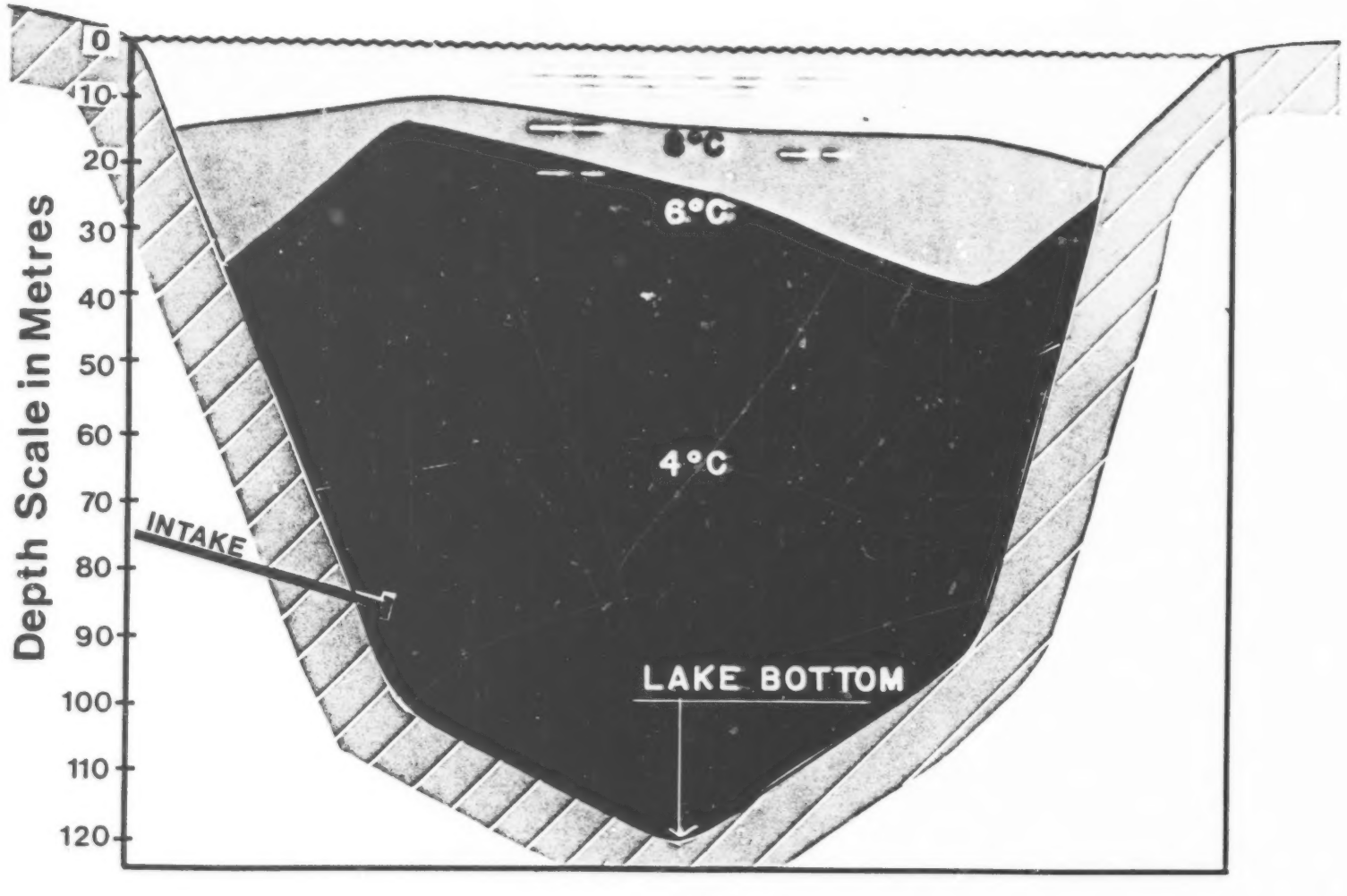


Fig. 3

CROSS SECTION
Lake Ontario Thermoclines
July 31

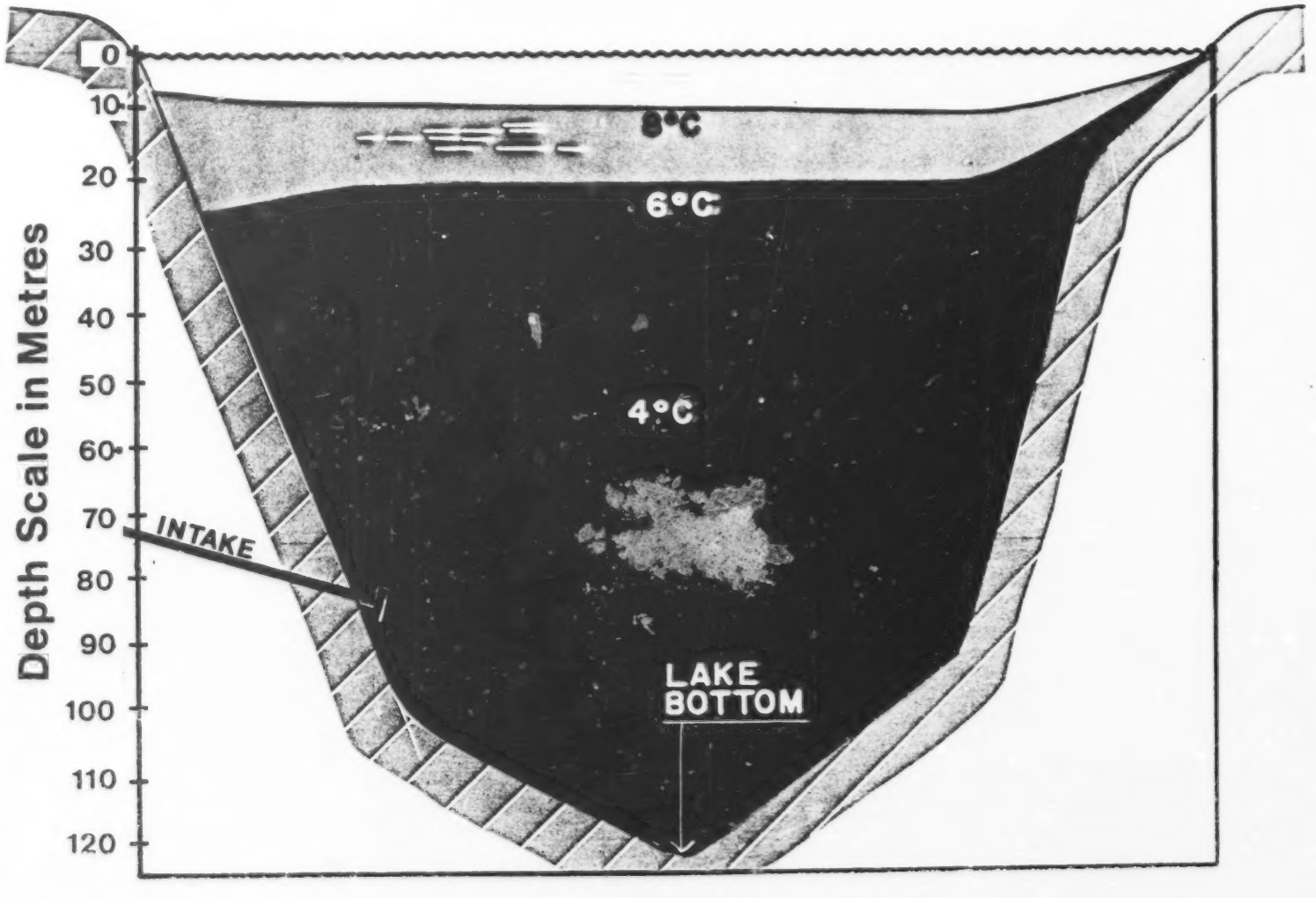


Fig. 4

CROSS SECTION
Lake Ontario Thermoclines
Aug. 14–17

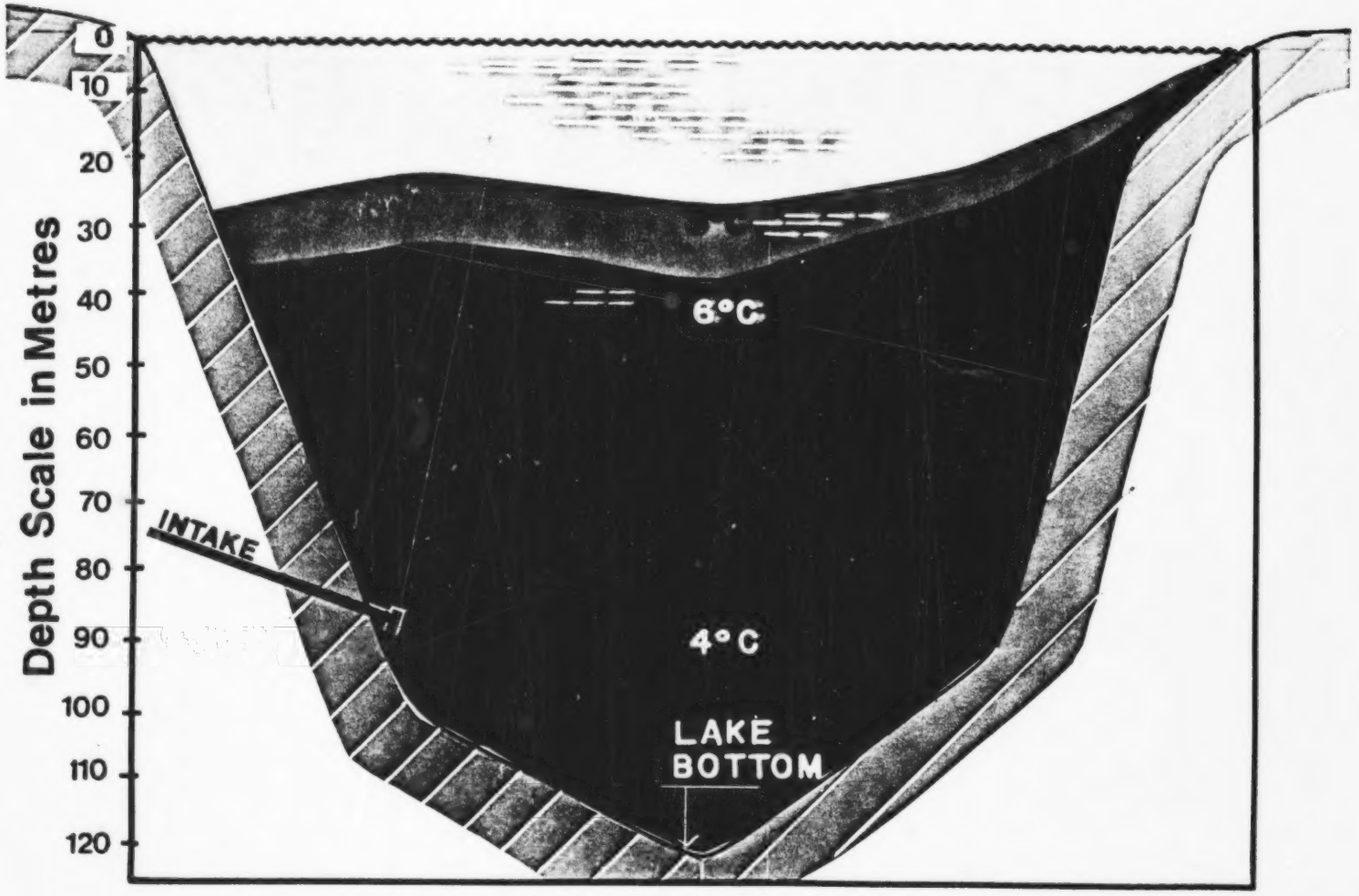


Fig. 5

CROSS SECTION
Lake Ontario Thermoclines
Sept.11-14

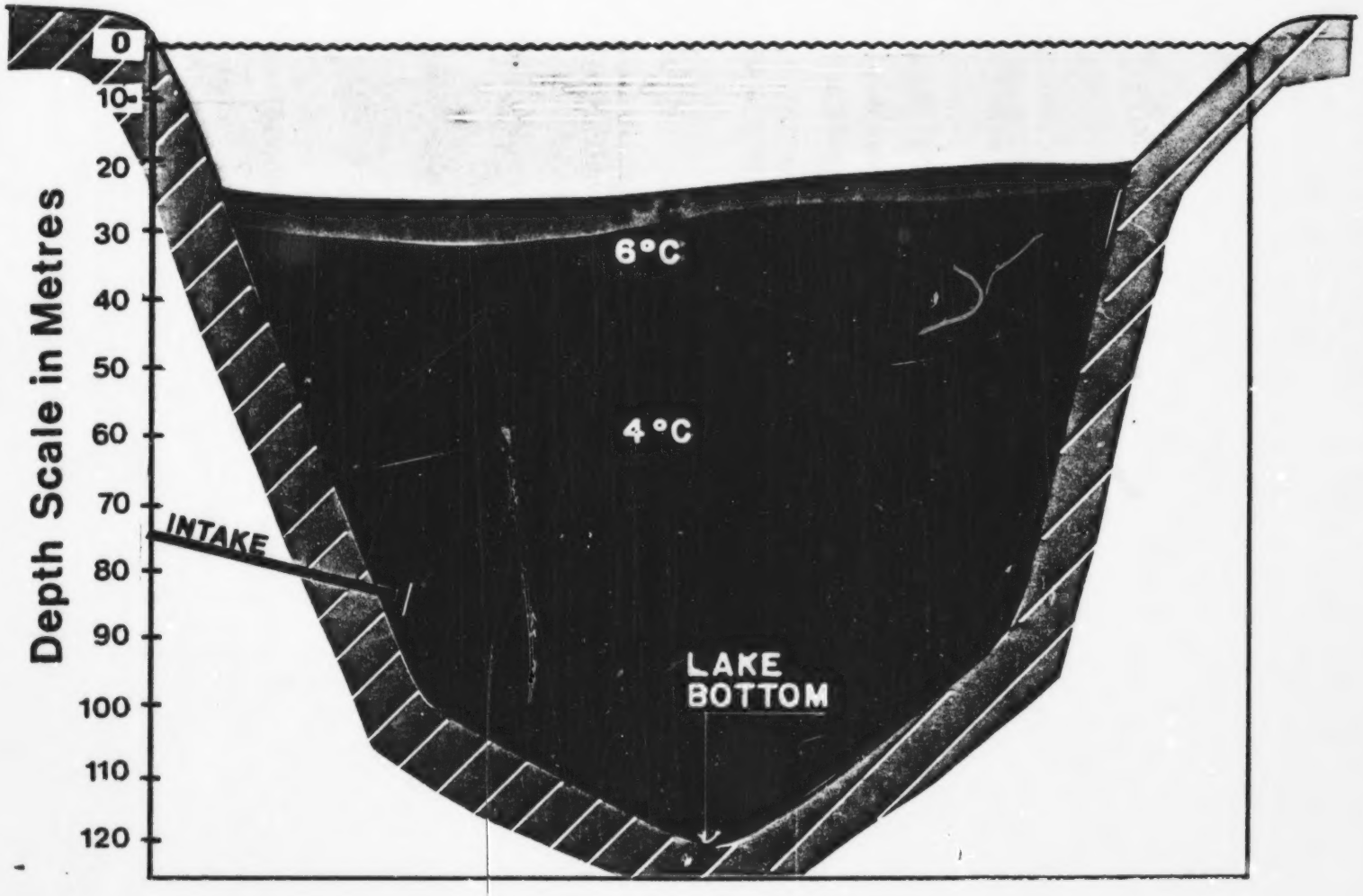


Fig. 6

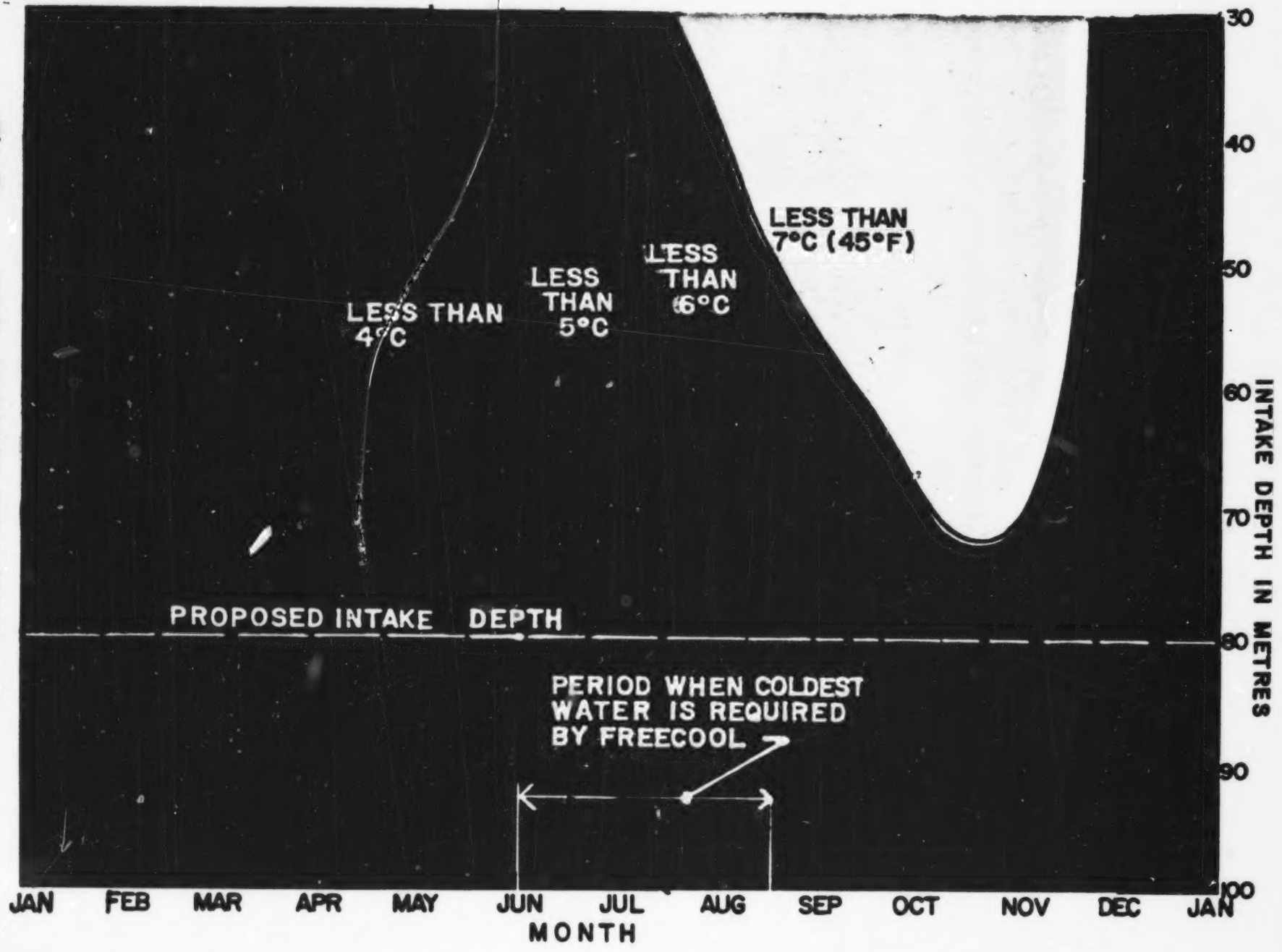
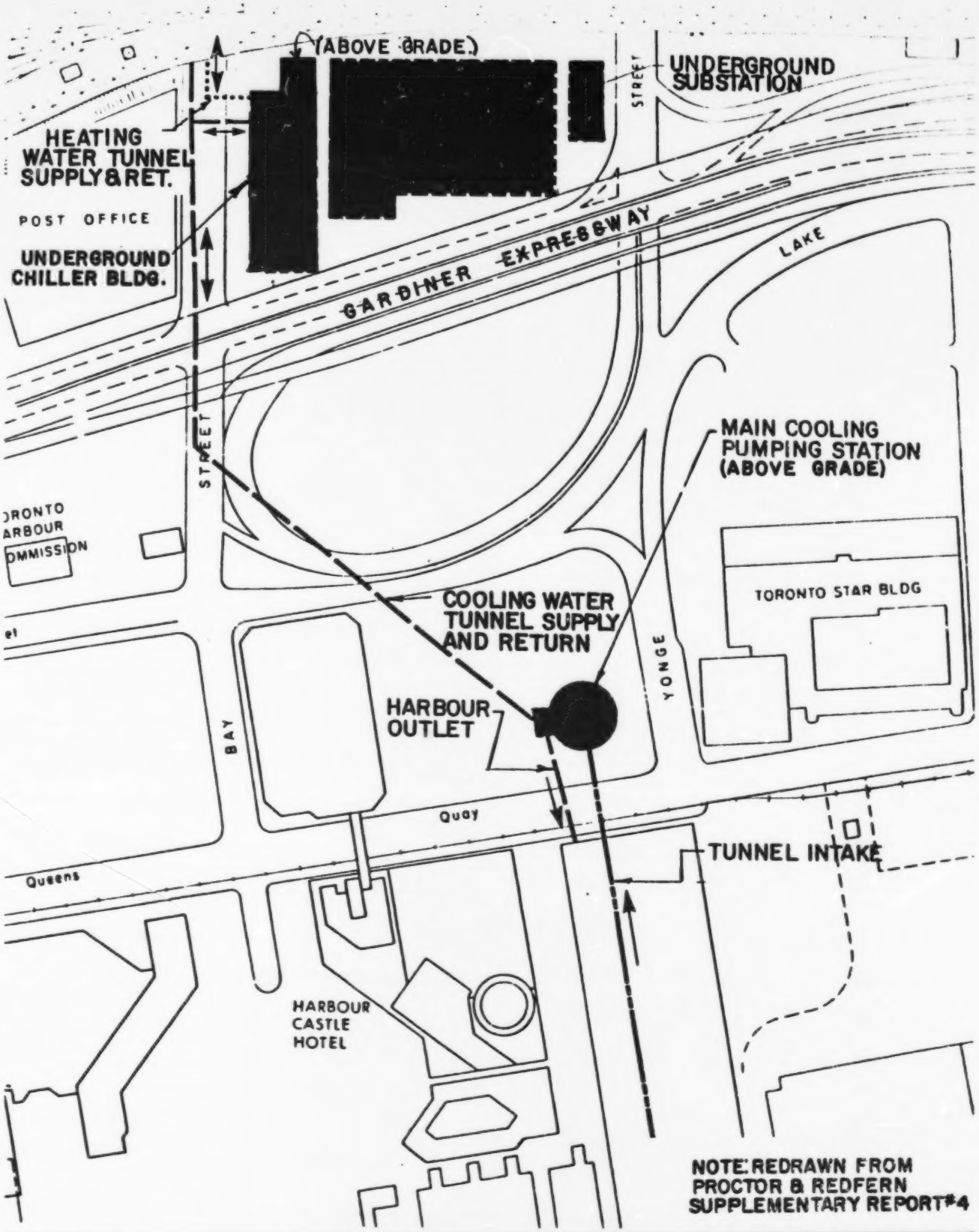


Fig. 7 100% PROBABILITY CURVES FOR LAKEWATER TEMPERATURE



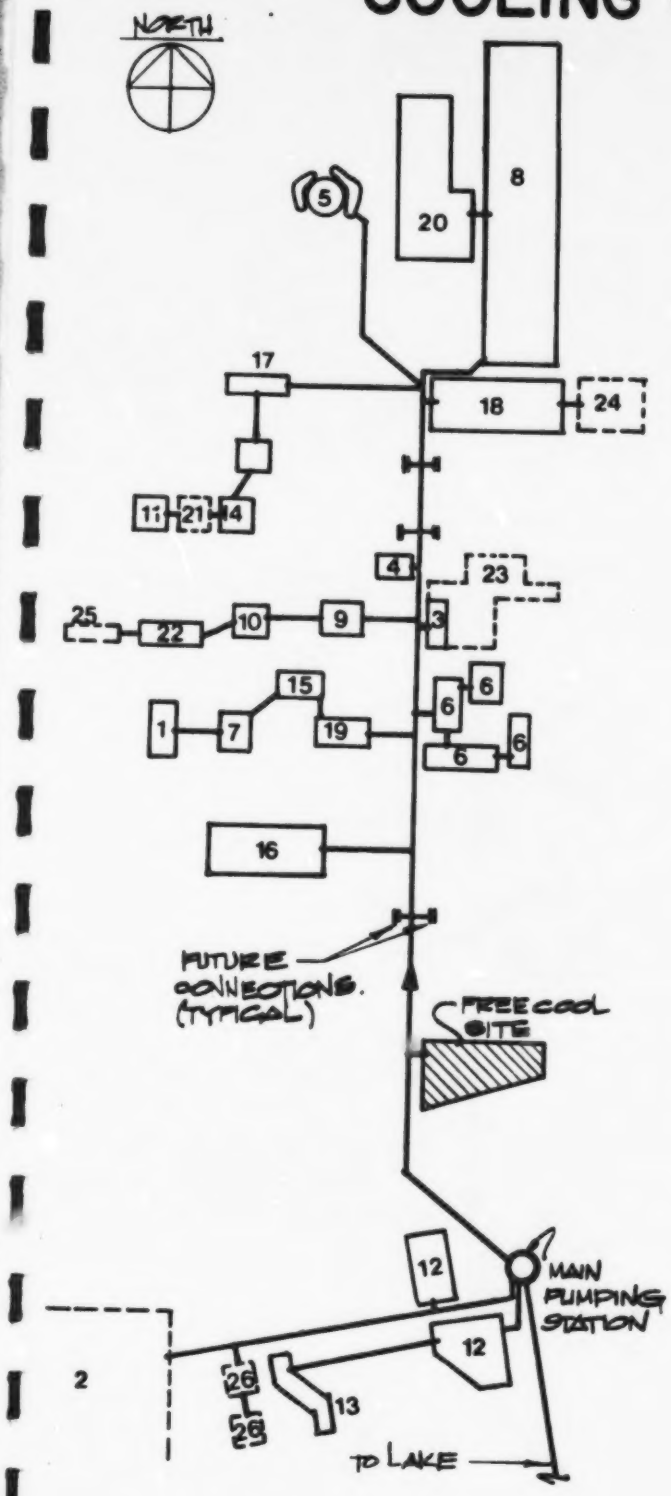
ENGINEERING INTERFACE LIMITED 2 SHEPPARD AVE. E. WILLOWDALE, ONT.	SPECULATIVE LOCATIONS FOR FREECOOL PLANT.	OCT., 1980 Fig.8

Name of Building	Maximum Heating Requireme for 49°C MJ/Hr.	Litres/Sec. Water @ 16.7°CΔT
111 Richmond St. West	1,426	6
Bank of Nova Scotia	5,992	24
City Hall	9,491	38
Commercial Union Building	18,097	72
Eaton Centre	15,958	63
First Canadian Place - Tower I	43,878	175
Guardian Life	5,992	24
Royal Trust Tower	37,019	147
Royal York Hotel	2,661	11
Simpson's Tower	6,179	25
Toronto-Dominion Bank	49,362	196
Oxrap	5,325	21
Sun Life Building	7,972	32
Bay-Yonge-King-Adelaide Addition	19,952	79
Fidinam	16,625	66
Harbourfront	66,491	265
Sun Life Addition	9,967	40
Commerce Court	41,884	167
New Harbourside Condominiums	9,491	38
390 Bay Street	5,992	24
Royal Bank Plaza	19,952	79
Domestic Hot Water (All Buildings)	42,215	168
Total	436,921	1,760

SUMMARY OF MAXIMUM HEATING REQUIREMENT IN 1988

Fig. 9

COOLING CUSTOMERS



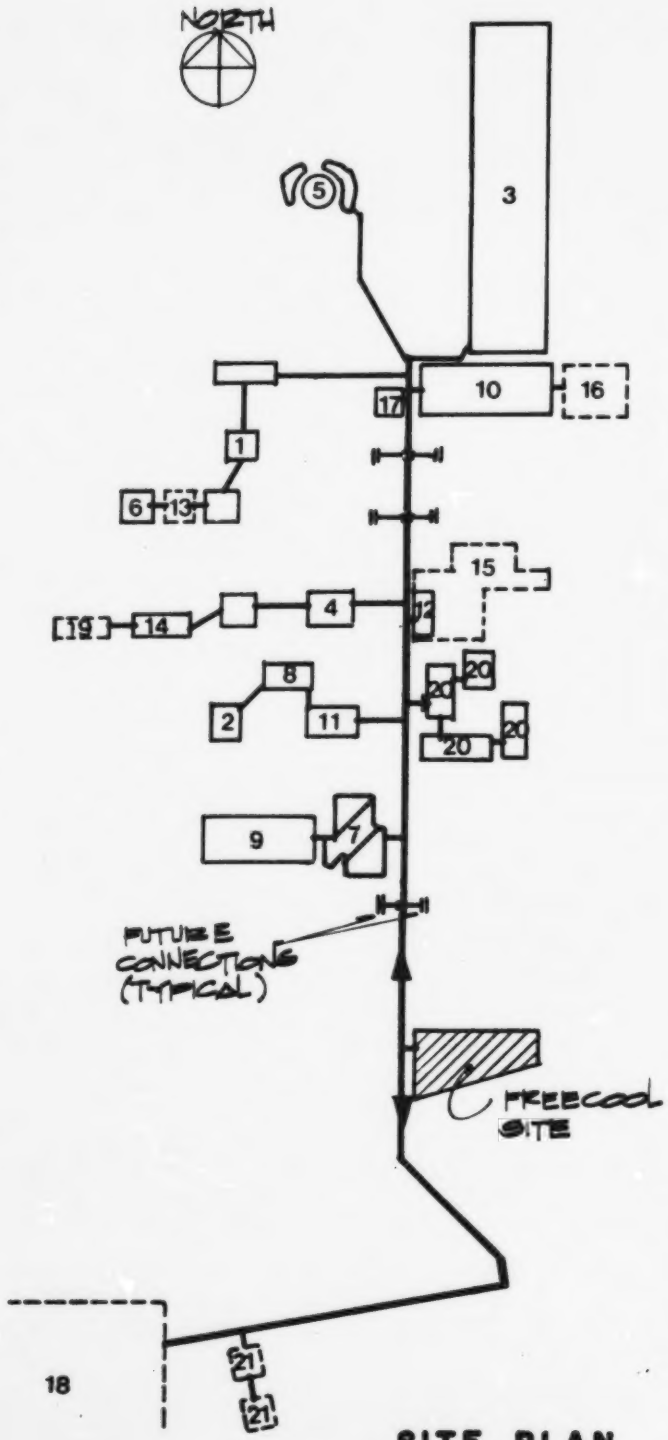
SITE PLAN

Fig. 10

Legend:

1. 55 University Avenue
2. Harbourfront
3. Bank of Nova Scotia
4. Canada Permanent Building
5. City Hall
6. Commerce Court
7. Commercial Union Building
8. Eaton Centre
9. First Canadian Place, Tower I
10. First Canadian Place, Tower II
11. Guardian Life
12. Harbour Castle Hotel/Convention Centre
13. Harbourside Condominiums
14. Richmond-Adelaide Centre II
15. Royal Trust Tower
16. Royal York Hotel
17. Sheraton Centre
18. Simpson's Store and Tower
19. Toronto-Dominion Bank
20. Bell Trinity Square
21. Oxrap
22. Sun Life
23. Bay-Yonge-King-Adelaide Addition
24. Fidinam
25. Sun Life Addition
26. Harbourside Condominiums

HEATING CUSTOMERS



SITE PLAN

Fig. 11

Legend:

1. 111 Richmond St. West
2. Commercial Union Building
3. Eaton Centre
4. First Canadian Place - Tower I
5. City Hall
6. Guardian Life
7. Royal Bank Plaza
8. Royal Trust Tower
9. Royal York Hotel
10. Simpson's Tower
11. Toronto-Dominion Bank
12. Bank of Nova Scotia
13. Oxrap
14. Sun Life Building
15. Bay-Yonge-King-Adelaide Addition
16. Fidinam
17. 390 Bay Street
18. Harbourfront
19. Sun Life Addition
20. Commerce Court
21. Harbourside Condominiums

FIGURE 12

ESTIMATED ANNUAL COOLING AND HEATING LOADS
FOR FREECOOL SYSTEM -- IN 1988

Building	Cooling Load (GJ)	Heating Load (GJ)
City Hall	93,493	25,337
Sheraton Centre	38,740	0
Bank of Nova Scotia	10,622	14,924
Commerce Court	324,141	104,467
Harbour Castle Hotel and Convention Centre	16,778	0
Harbourside Condominiums	16,612	0
Simpson's Store and Tower	46,556	16,469
Guardian Life	19,198	14,924
Richmond-Adelaide Phase II	23,502	0
First Canadian Place - Tower I	173,507	109,443
Toronto-Dominion Bank	54,246	131,674
Royal Trust Tower	61,400	98,761
Commercial Union Tower	29,260	48,291
Eaton Centre	63,930	39,797
Eaton Tower I	20,954	0
Eaton Tower II	17,828	0
111 Richmond Street West	0	3,800
55 University Avenue	8,464	0
390 Bay Street	0	14,924
Royal Bank Plaza	0	49,747
Royal York Hotel	30,869	6,633

FIGURE 12 (contd)

Canada Permanent Building	10,622	0
Bell Trinity Square	15,194	0
Sun Life Building	26,445	19,899
First Canadian Place - Tower II	26,445	0
Oxrap Building	17,067	13,266
Fidinam Building	53,334	41,457
Bay-Yonge-King-Adelaide Addition	63,992	49,747
New Sun Life Building	32,006	24,874
New Harbourside Condominiums	8,320	25,337
Harbourfront	213,298	165,829
Miscellaneous Cooling	29,518	0
Domestic Hot Water (all Buildings)	0	131,583
Total	1,546,341	1,151,183

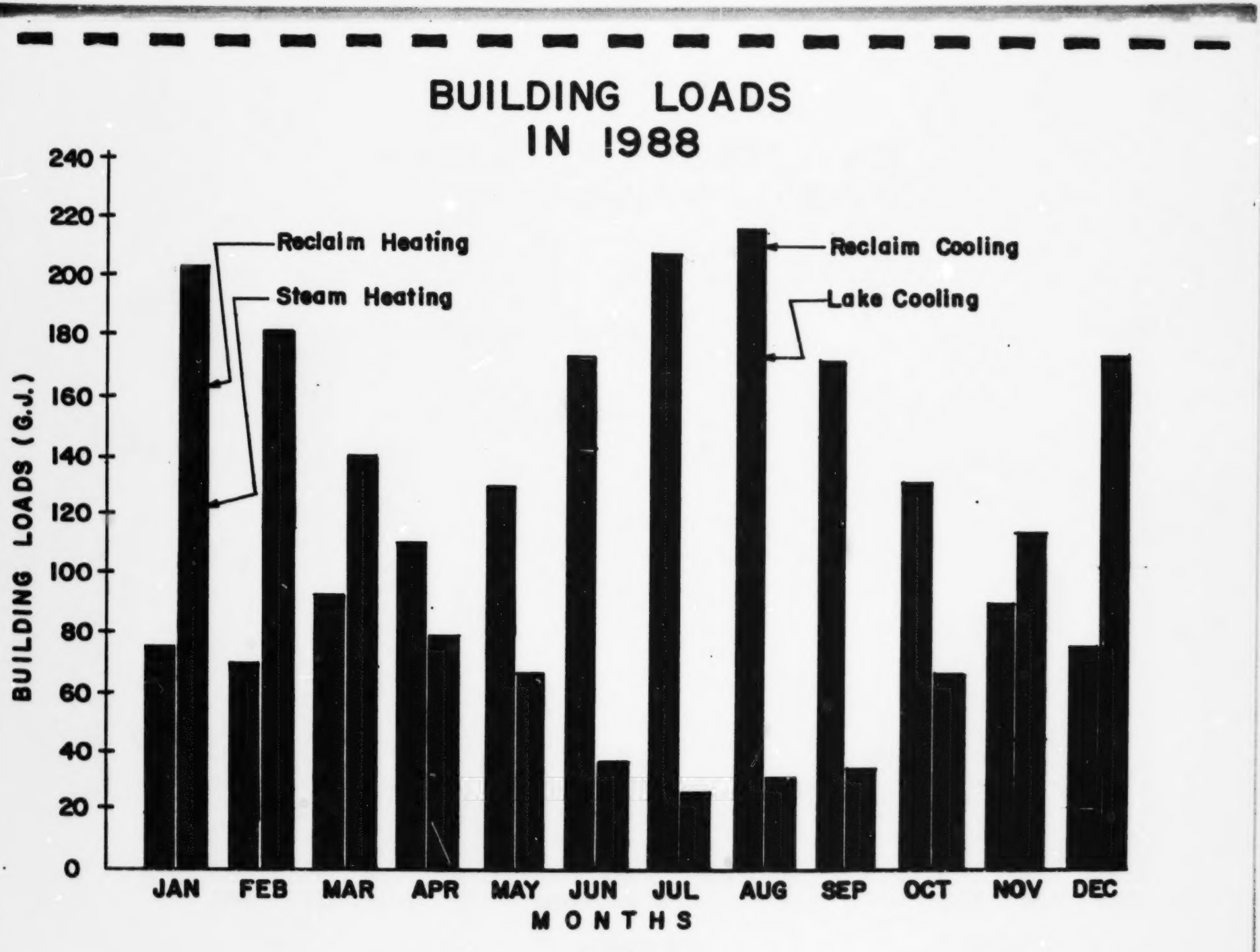

BUILDING LOADS
IN 1988
BUILDING LOADS (G.J.)
240
220
200
180
160
140
120
100
80
60
40
20
0
Reclaim Heating
Steam Heating
Reclaim Cooling
Lake Cooling
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTHS

Fig. 13

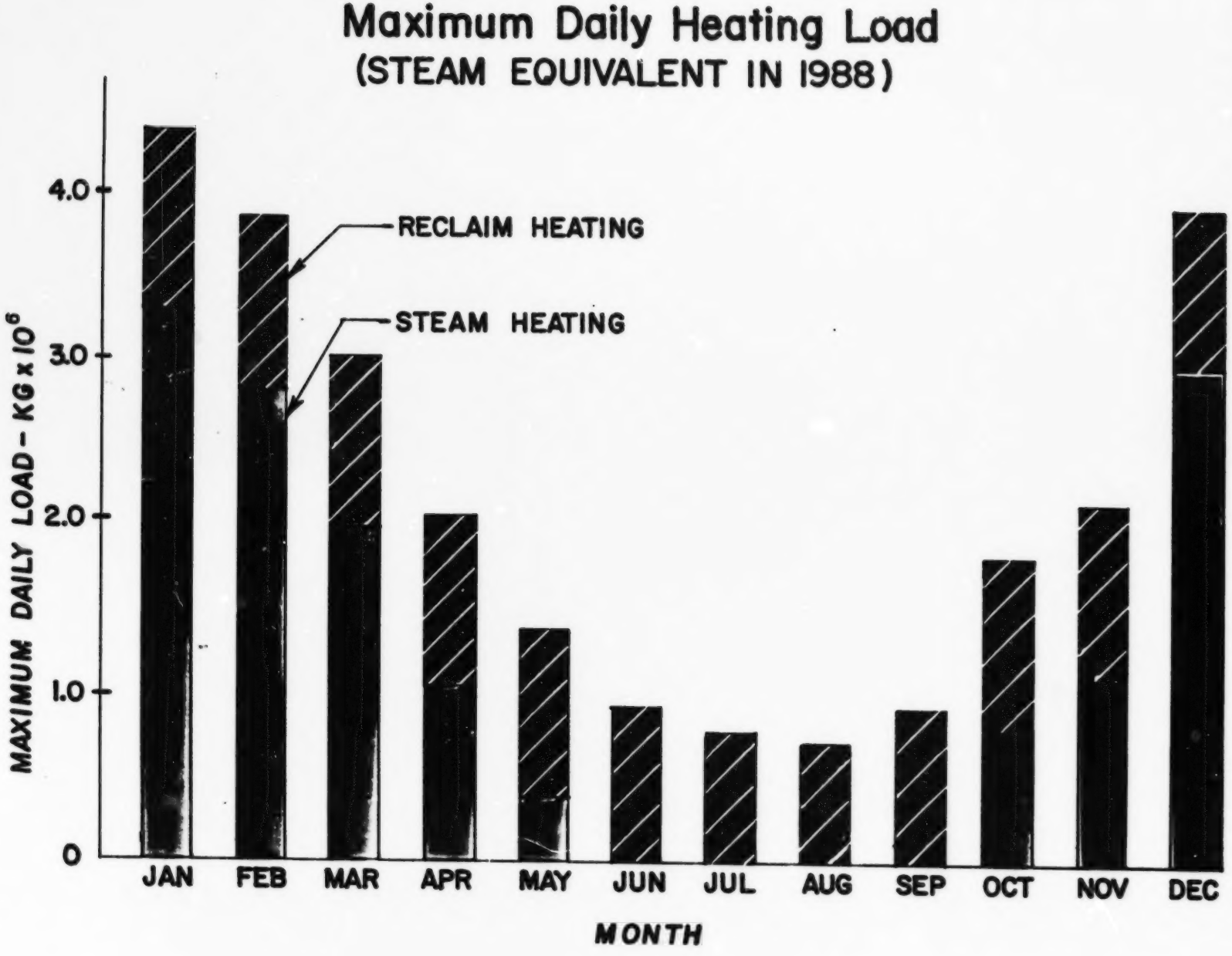

Maximum Daily Heating Load
(STEAM EQUIVALENT IN 1988)
RECLAIM HEATING
STEAM HEATING
MAXIMUM DAILY LOAD - KG x 10^6
4.0
3.0
2.0
1.0
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Fig. 14

FREECOOL MONTHLY COOLING AND HEATING LOADS - IN 1988*

	Cooling Loads - GJ			Heating Loads - GJ		
Month	From Lakewater Cooling	From Chillers	Total	From Heat Reclaim	From Central Steam	Total
January	17,800	58,500	76,300	73,400	130,700	204,100
February	16,700	52,900	69,600	66,200	115,300	181,500
March	33,600	59,100	92,700	72,900	67,300	140,200
April	58,000	53,000	111,000	68,900	9,600	78,500
May	79,400	51,500	130,900	61,400	5,000	66,400
June	143,800	29,800	173,600	36,400	0	36,400
July	186,900	21,100	208,000	26,500	0	26,500
August	194,300	23,500	217,800	29,400	0	29,400
September	145,300	26,500	171,800	33,600	0	33,600
October	83,300	47,600	130,900	60,500	5,200	65,700
November	30,500	57,700	88,200	72,200	42,900	115,100
December	19,200	56,300	75,500	73,000	101,000	174,000
Total	1,008,800	537,500	1,546,300	674,400	477,000	1,151,400

* These values are increased by approximately 93% for cooling and 87% for heating for the ultimate loads in the year 2001.

Fig. 15

Freecool Cooling Circuit Without Reclaim Heating

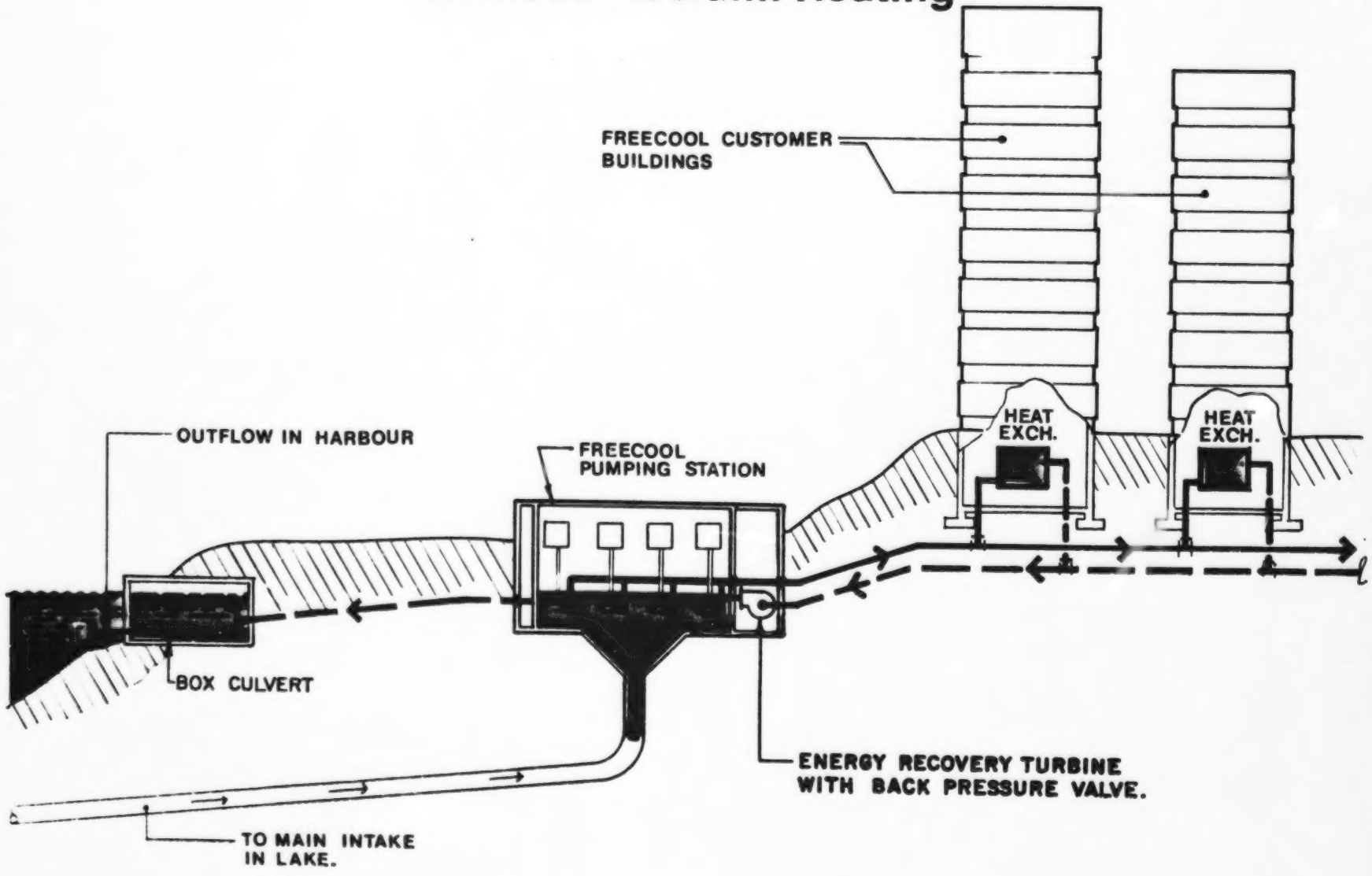
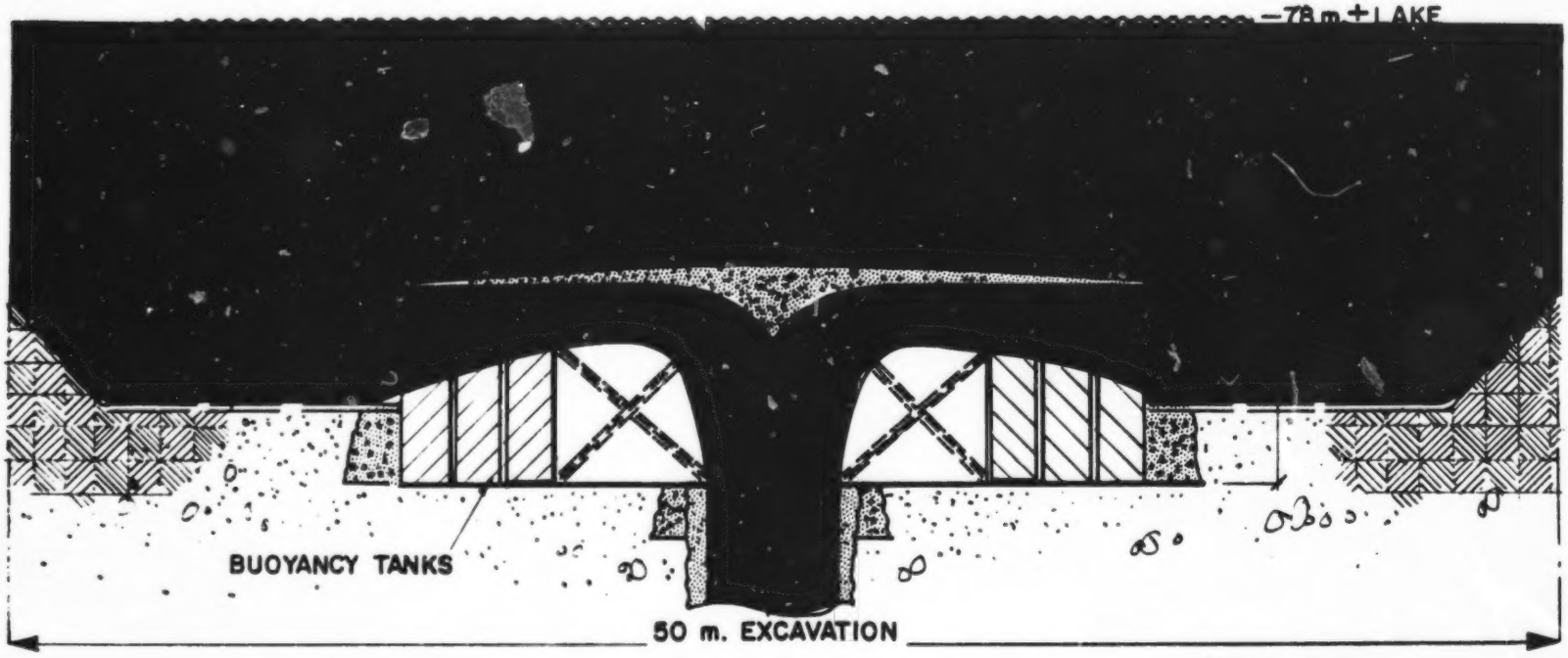


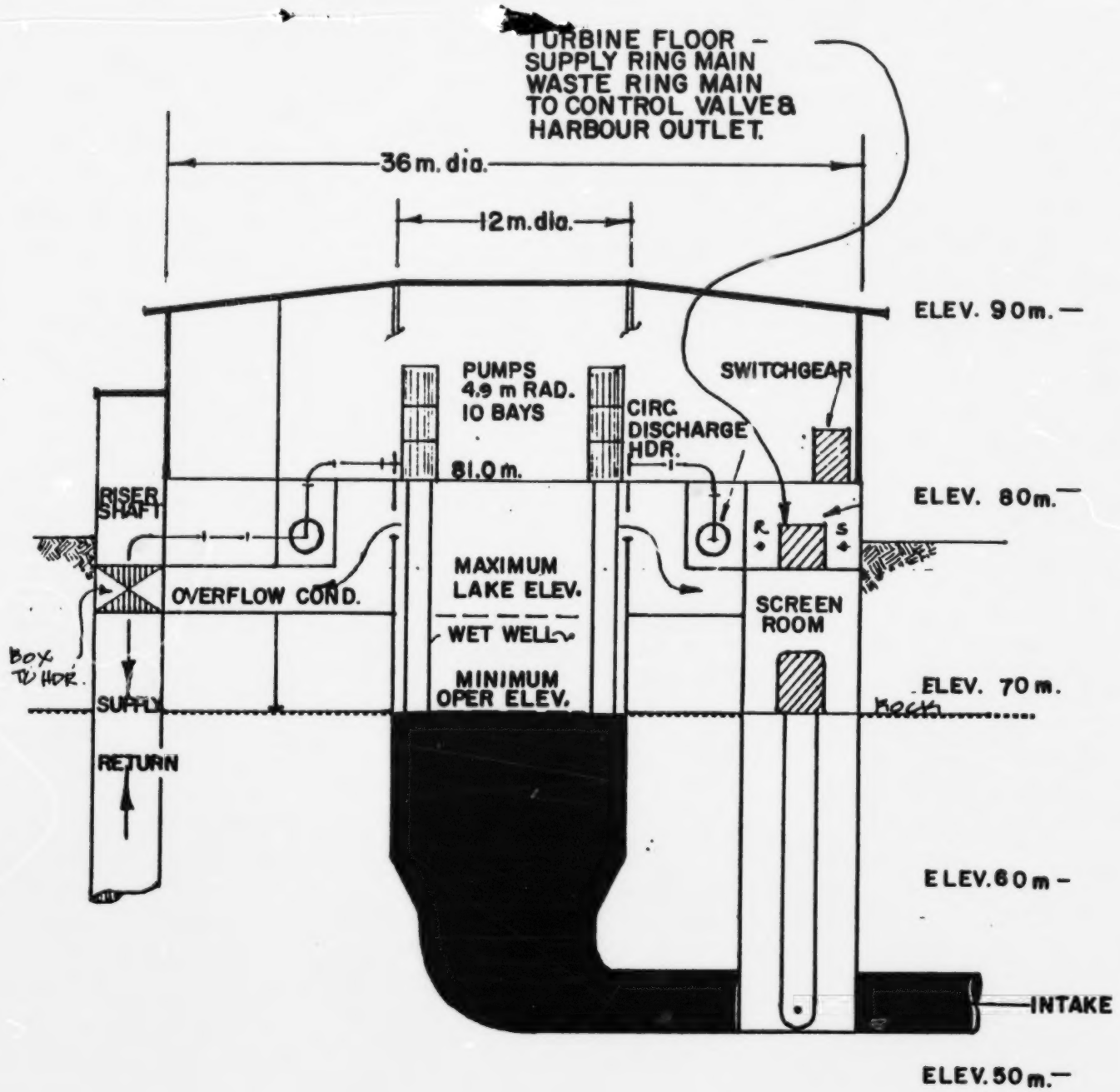
Fig.16



SCALE : NTS

TYPICAL INTAKE STRUCTURE IN ROCK

Fig. 17



ENGINEERING INTERFACE LIMITED 2 SHEPPARD AVE. E. WILLOWDALE, ONT.	MAIN PUMPING STATION PRELIMINARY LAYOUT	OCT., 1980 Fig. 18

Main Freecool Supply Pumps Electrical Demand As A Function Of Flow Rate

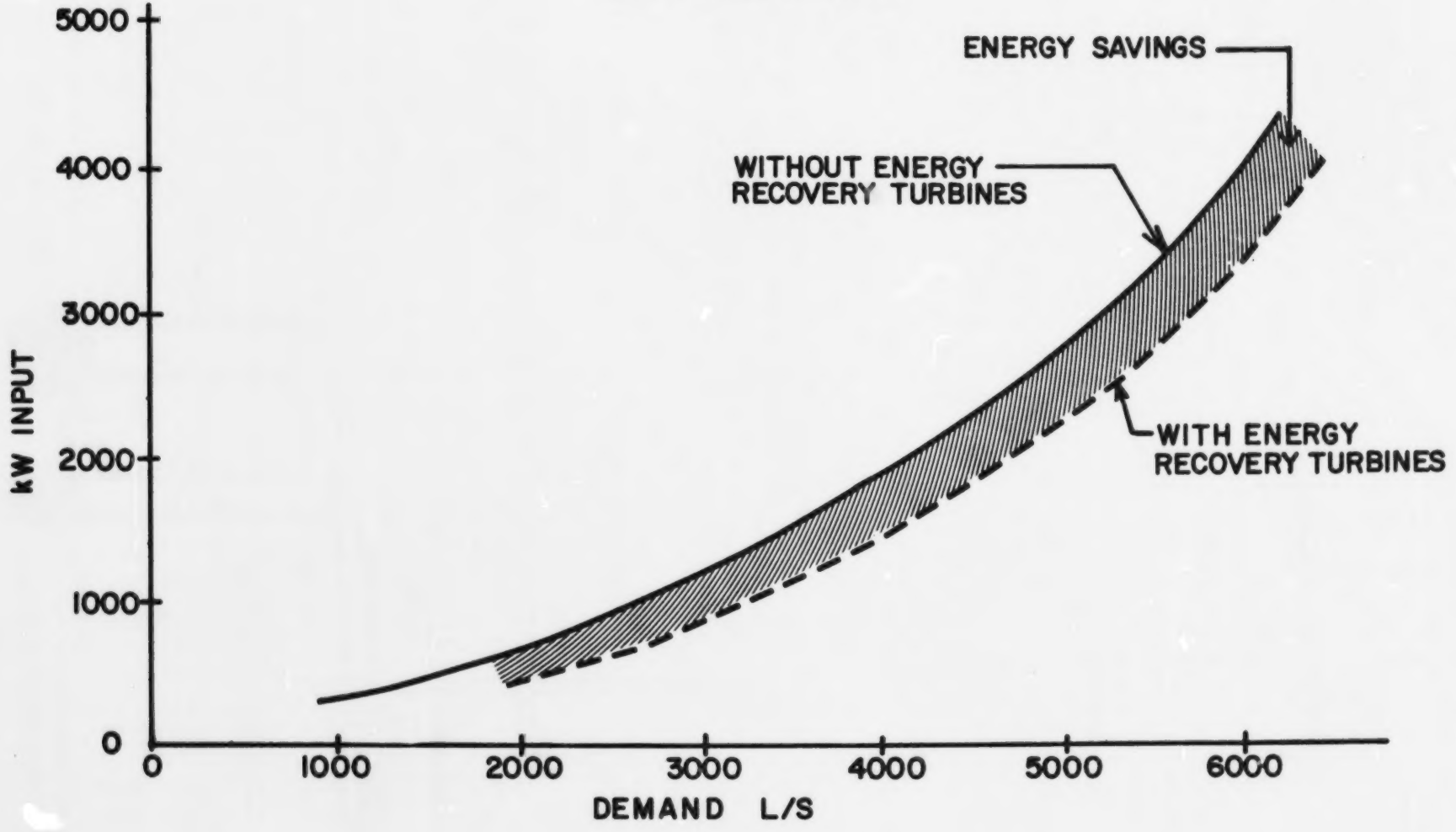
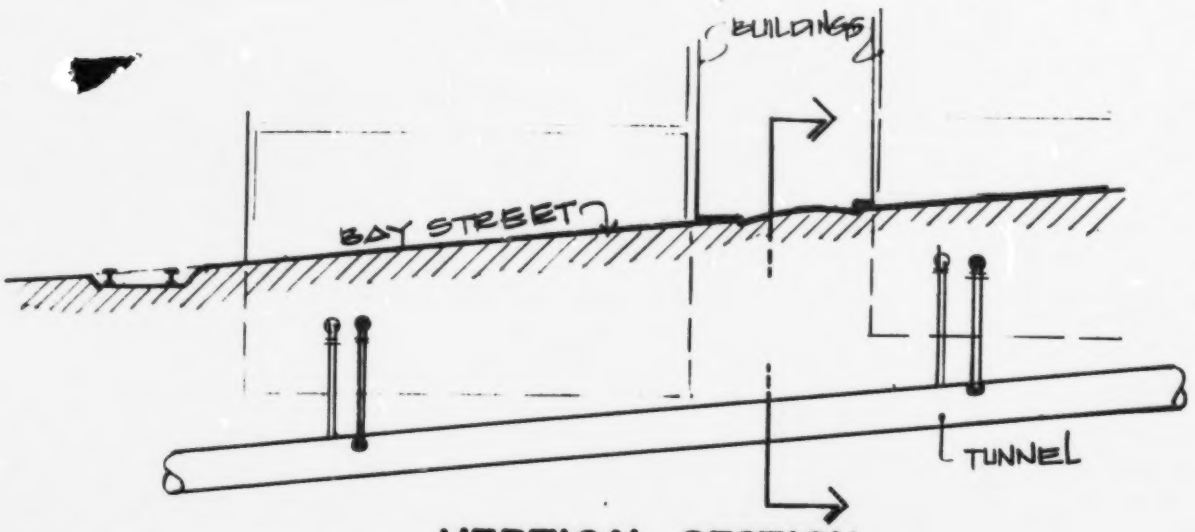


Fig. 19



VERTICAL SECTION ALONG BAY STREET

N.T.S.

SECTION 'A-A'

N.T.S.

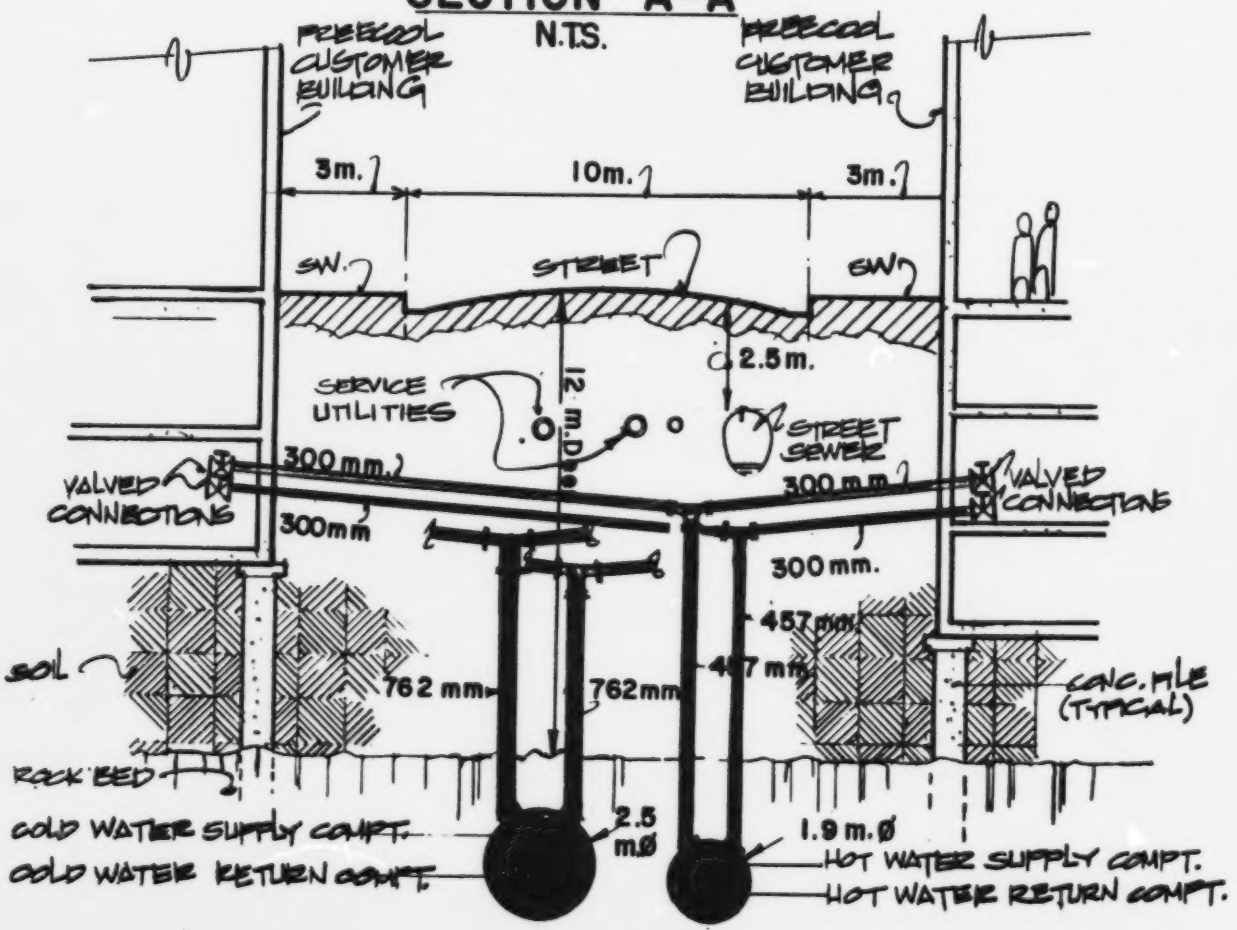
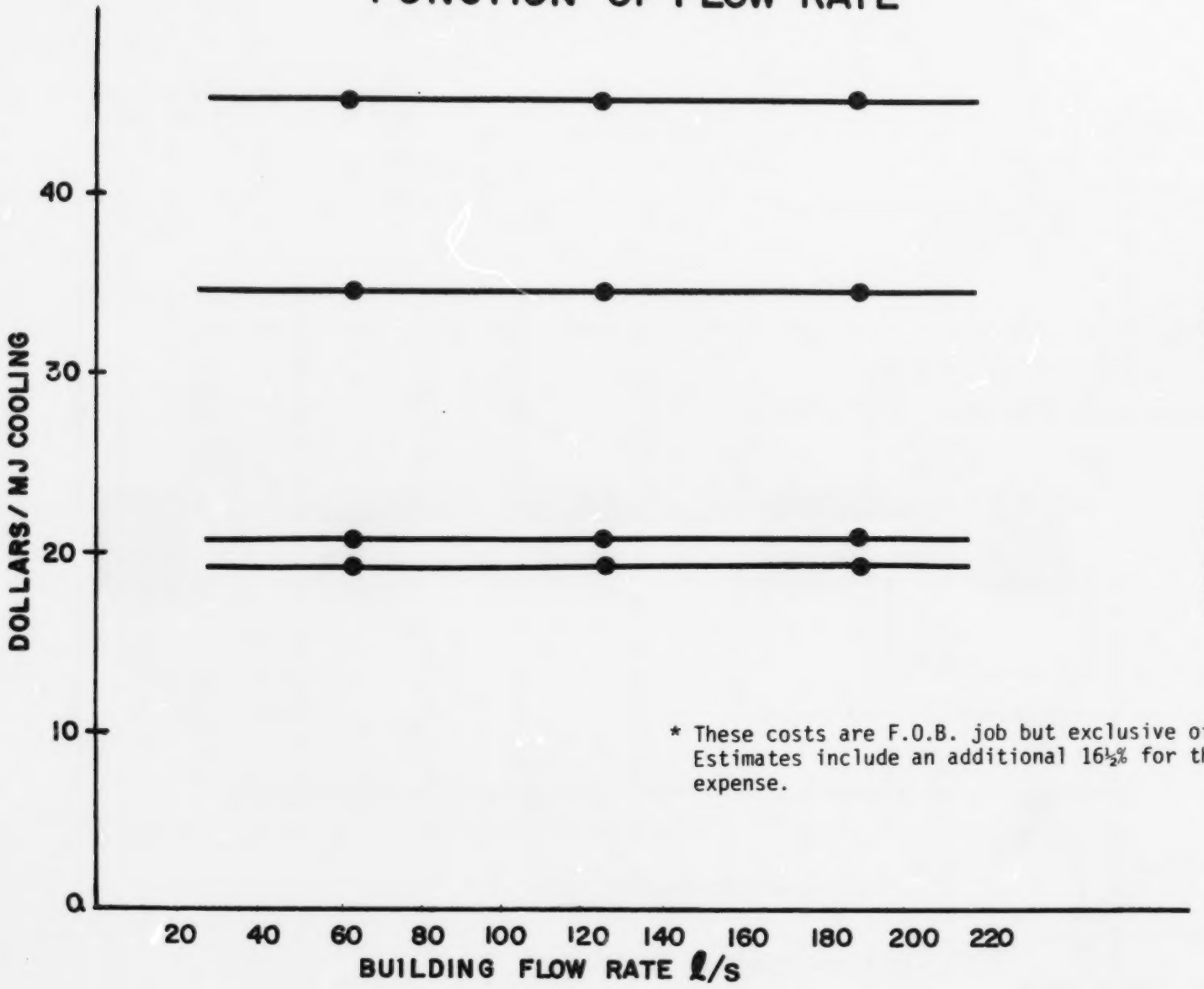


Fig. 20

HEAT EXCHANGER PRICES* AS A FUNCTION OF FLOW RATE



* These costs are F.O.B. job but exclusive of taxes. Estimates include an additional 16½% for this expense.

Fig. 21

Details Of Freecool Connection In Customer Space

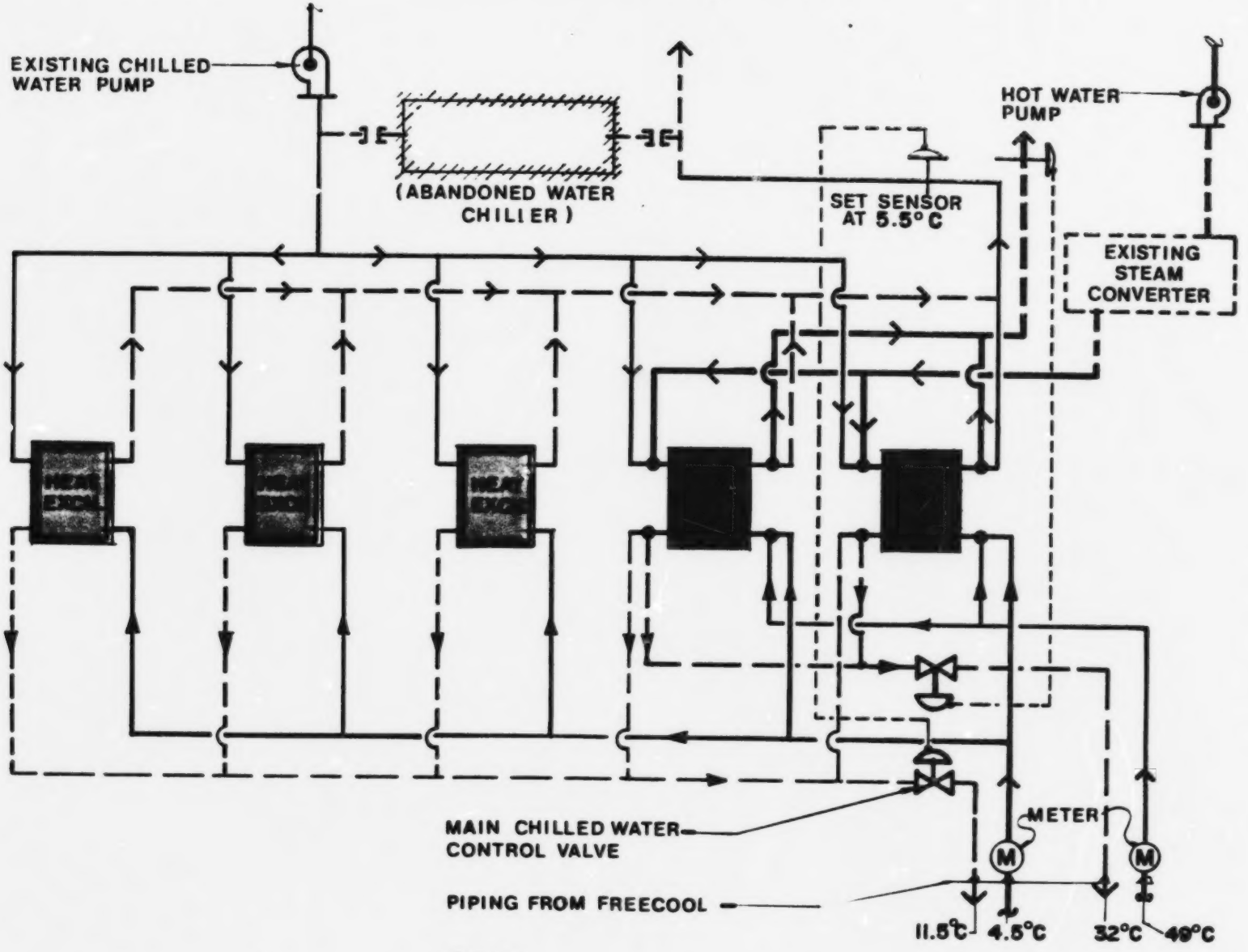


Fig.22

PROPOSED ONTARIO HYDRO RATE TO TORONTO HYDRO IN 1982

Direct Large User Monthly Rate Schedule

	"Existing"	Proposed
Energy per kWh		
Winter Peak	1.32	2.04
Winter Offpeak	1.32	1.97
Summer Peak	1.32	1.53
Summer Offpeak	1.32	1.35
Demand per kW		
230 kV Firm		
Winter	$5.44	$3.62*
Summer	$5.44	$2.42*
115 kV Firm		
Winter	$5.57	$3.75*
Summer	$5.57	$2.55*
10-50 kV Firm		
Winter	$6.02	$4.86
Summer	$6.02	$3.66
10 kV Firm		
Winter	$6.38	$5.22
Summer	$6.38	$4.02
Toronto Hydro Demand Charge per kW in offpeak period	-	$1.00

*Discontinuance of the difference between the 115 kV and 230 kV demand changes is being considered for the 1982 rates.**

TIME PERIODS

SEASON	PEAK	OFF-PEAK
WINTER (September-March)	7 a.m. to 11 p.m. weekdays except Statutory Holidays	All other times
SUMMER (April - August)	7 a.m. to 11 p.m. weekdays except Statutory Holidays	All other times

**This concept for time of day pricing may now be postponed to the year 1984.

Fig. 23

January 1, 1979 S-03-01

DISTRICT STEAM SERVICE

BASIC RATES

The amount of Steam supplied will be paid for on the basis of total monthly consumption measured by steam flow meters at the following basic rates:

$6.20 per thousand pounds for the first 50 thousand pounds of steam per month

$5.65 per thousand pounds for the next 150 thousand pounds of steam per month

$5.40 per thousand pounds for the next 800 thousand pounds of steam per month

$5.05 per thousand pounds for the next 3000 thousand pounds of steam per month

$4.85 per thousand pounds for the next 5000 thousand pounds of steam per month

$4.65 per thousand pounds for all remaining pounds of steam per month

Minimum Bill - $80.00 for each month except June, July and August

Fuel Cost Adjustment - See S-04

For September 1981, add $3.36/M lbs. to all categories of building.

Fig. 24

Energy Recovery Type Recirculation Pumps

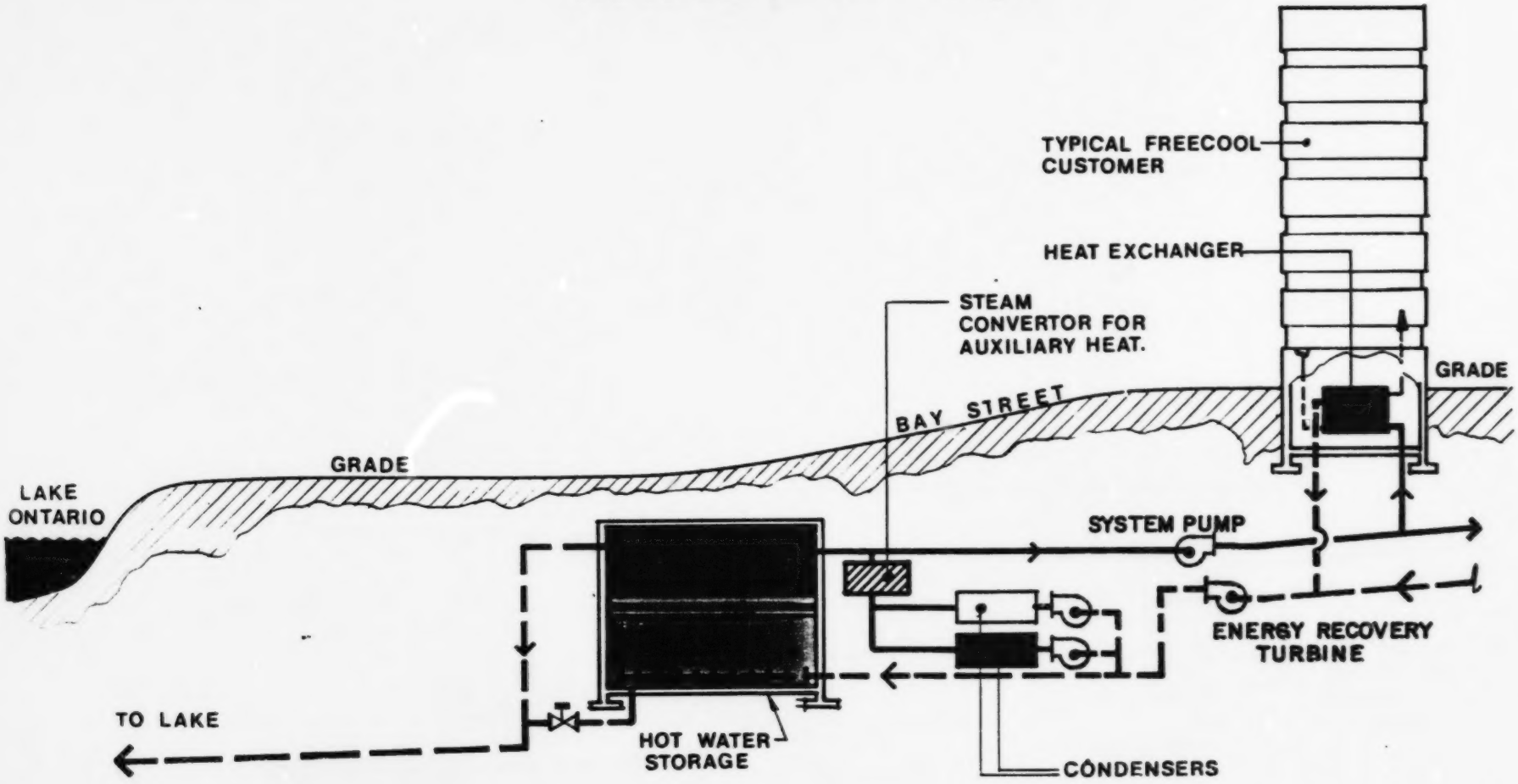


Fig. 25

Cooling Circuit For Freecool Including Winter Recirculation For Heat Reclaim

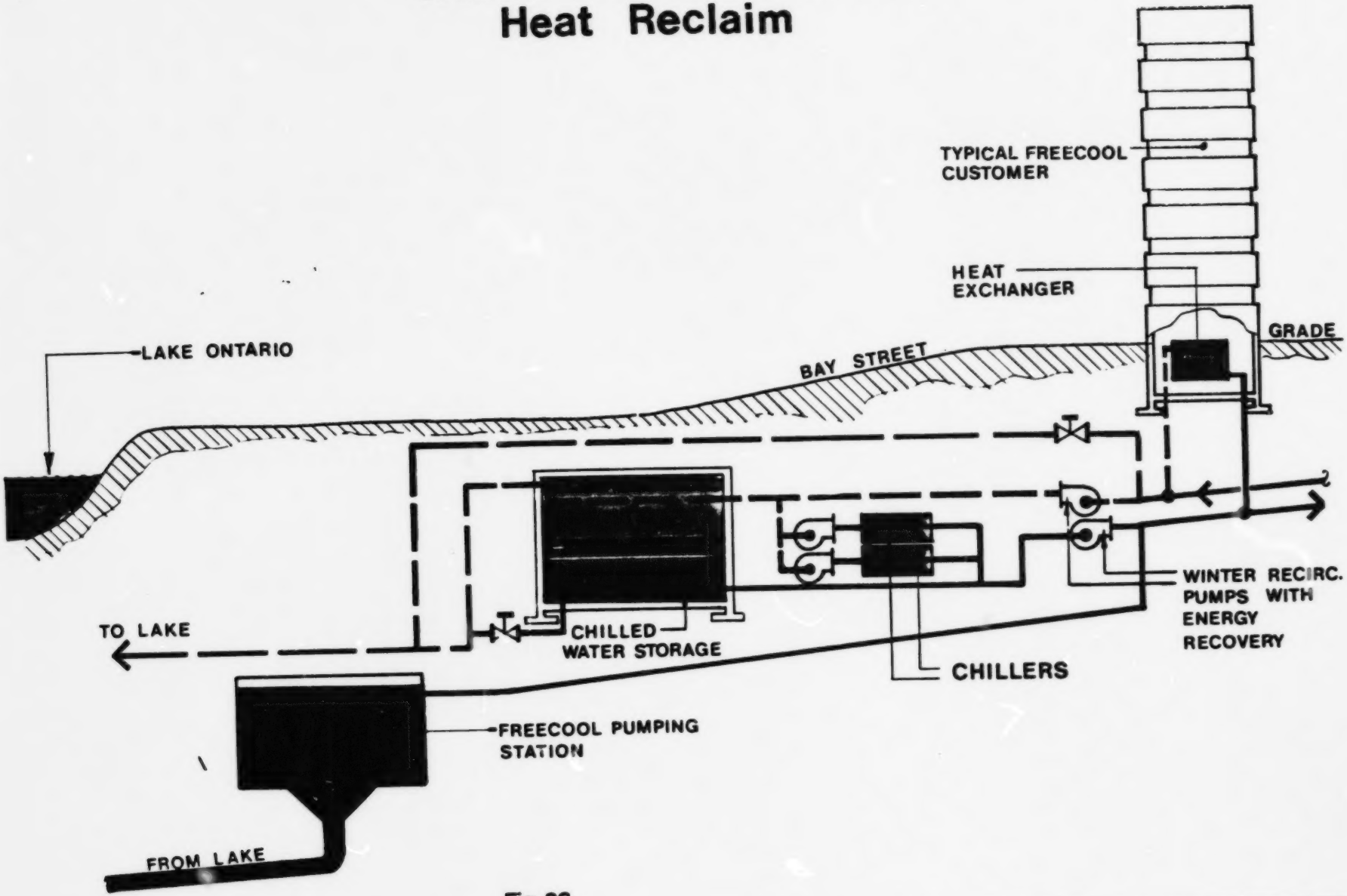
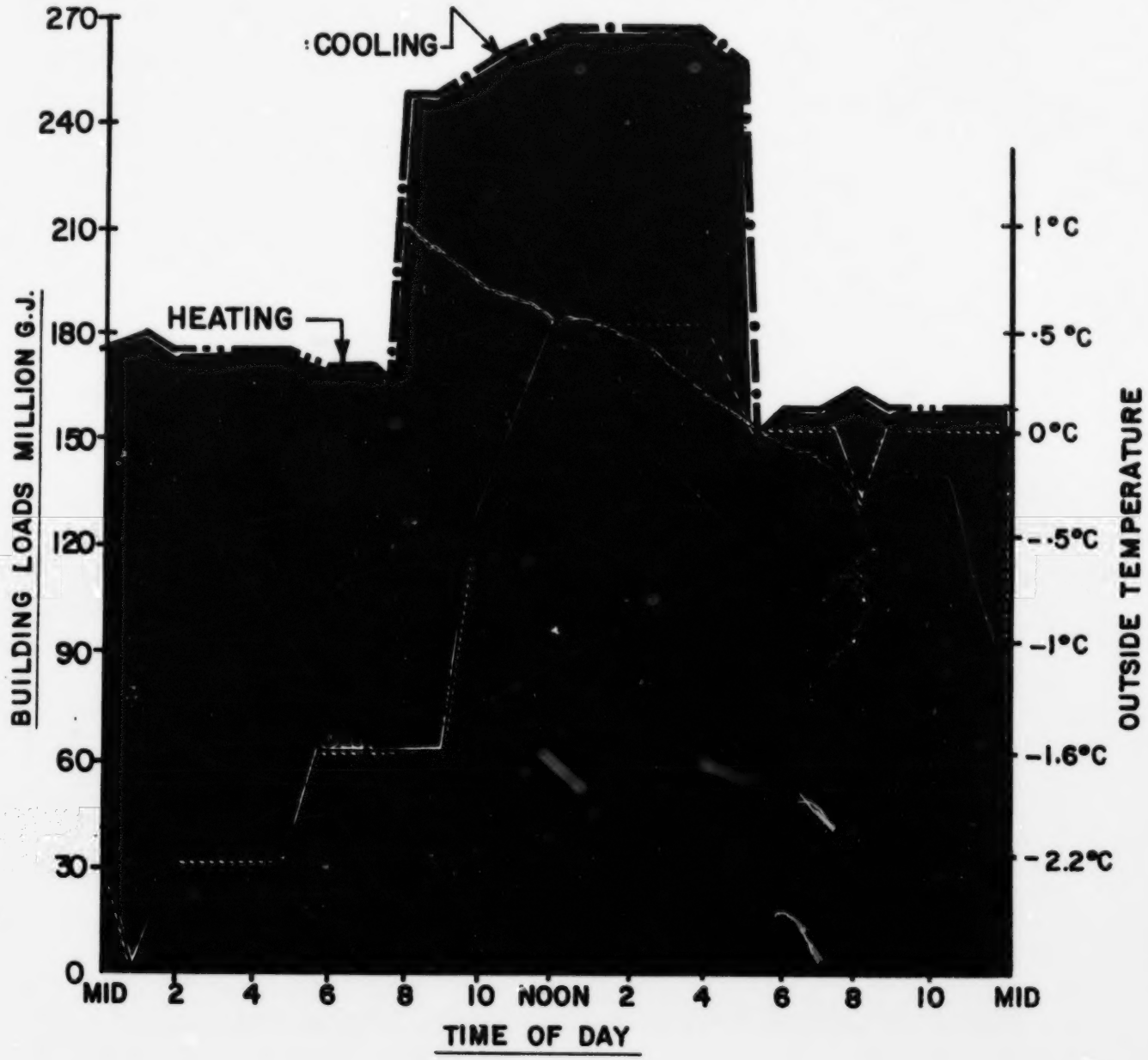


Fig. 26

1988
Freecool Profiles On A Day Of Maximum Heat Transfer

A DAY WHICH AVERAGES-1°C

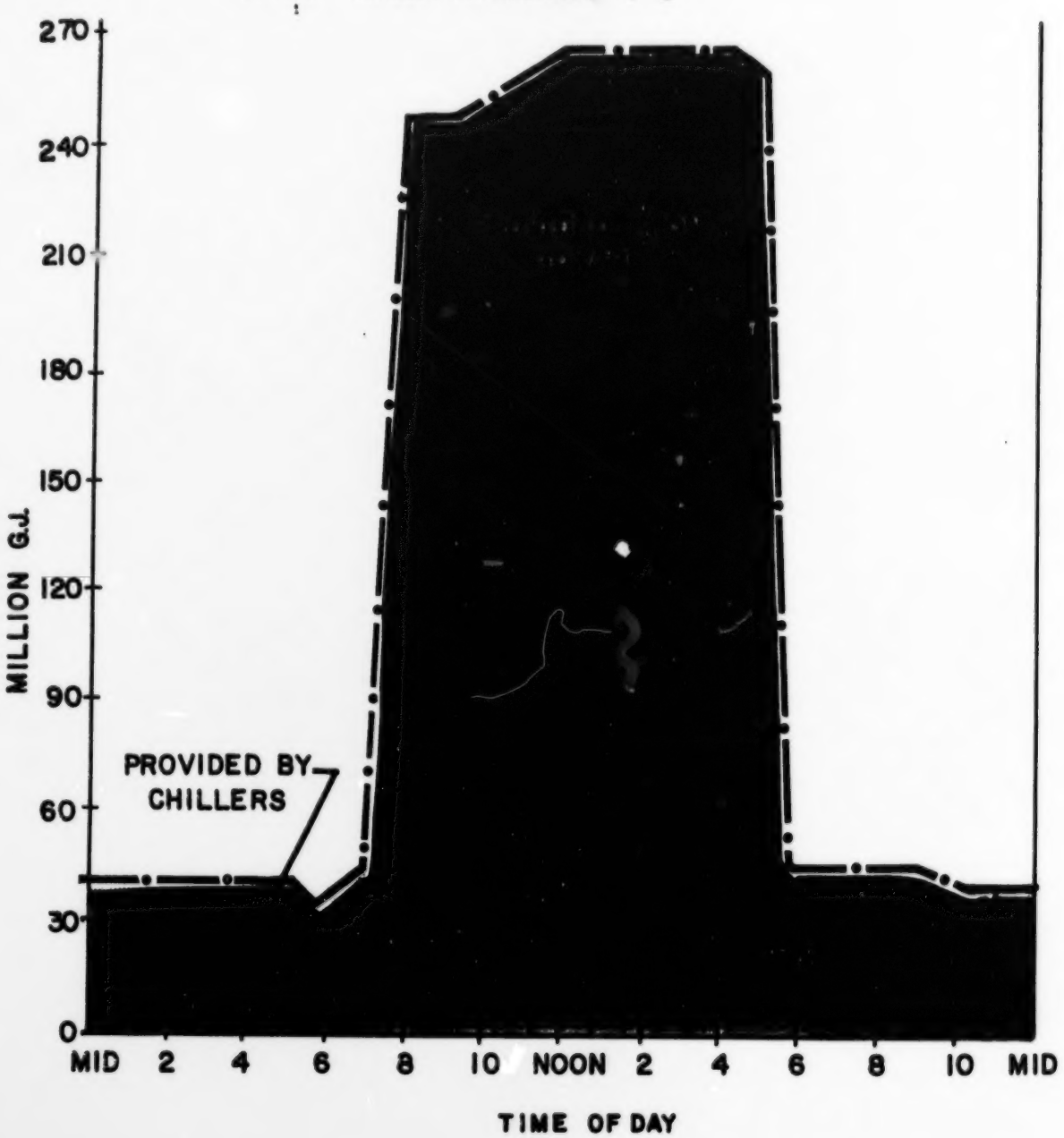


NOTE: THE AREA UNDER THE COOLING REQUIREMENT CURVE WHEN AUGMENTED WITH THE CHILLER WORK HEAT EQUALS THE AREA UNDER THE HEATING REQUIREMENT CURVE.

Fig. 27a

1988
Cooling Load Profile On A Day Of Maximum Heat Transfer

A DAY WHICH AVERAGES – 1°C

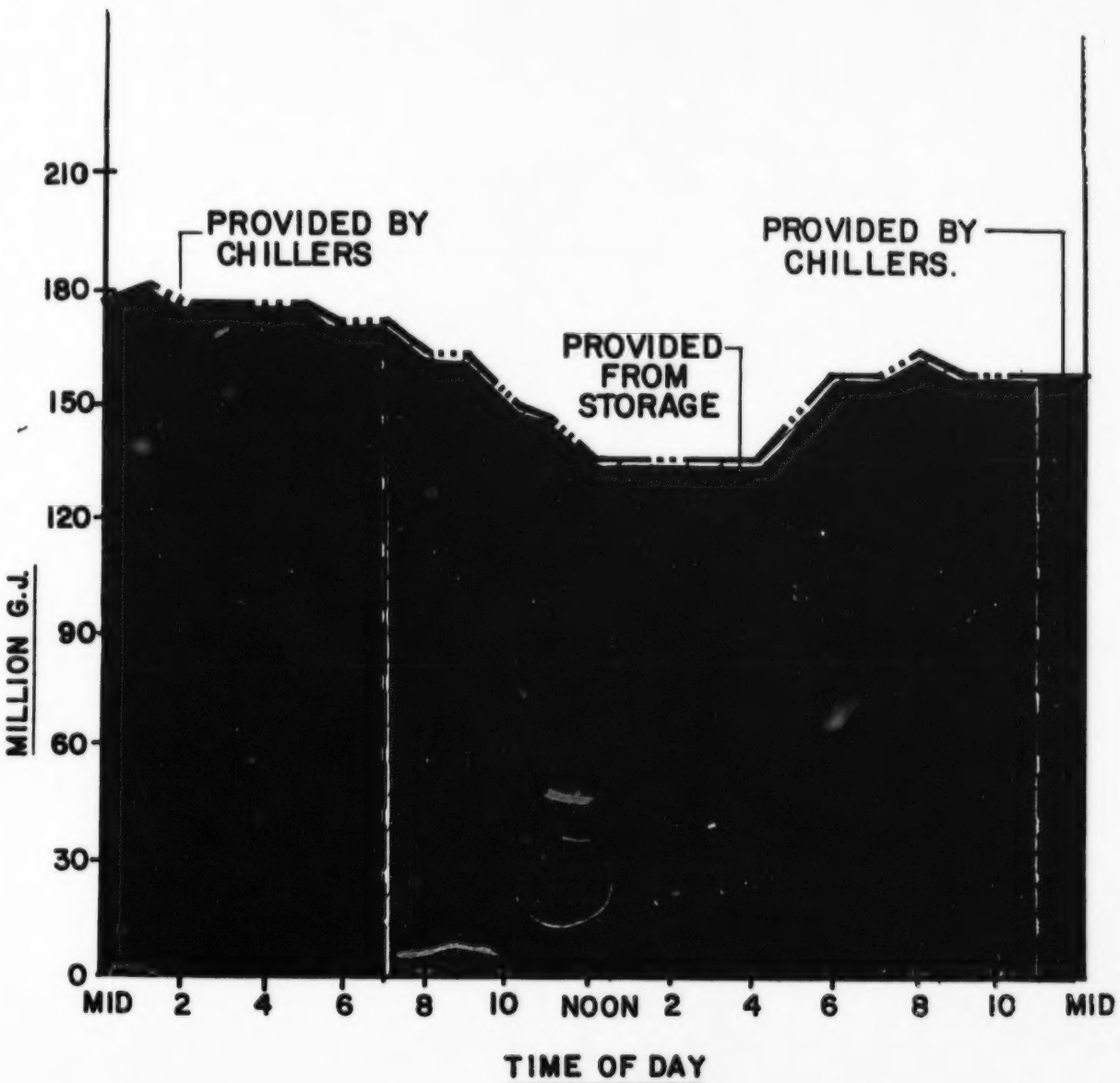


NOTE: HEAT RECLAIMING CHILLERS CAN OPERATE ONLY DURING THE NETWORK OFF-PEAK PERIOD 11 P.M. TO 7 A.M.

Fig. 27b

1988
Heating Load Profile On A Day Of Maximum Heat Transfer

A DAY WHICH AVERAGES -1° C



NOTE: HEAT RECLAIMING CHILLERS CAN OPERATE ONLY DURING THE NETWORK OFF-PEAK PERIOD 11 P.M. TO 7A.M.

Fig. 27c

SERIES FLOW ARRANGEMENTS OF CHILLERS AND CONDENSERS

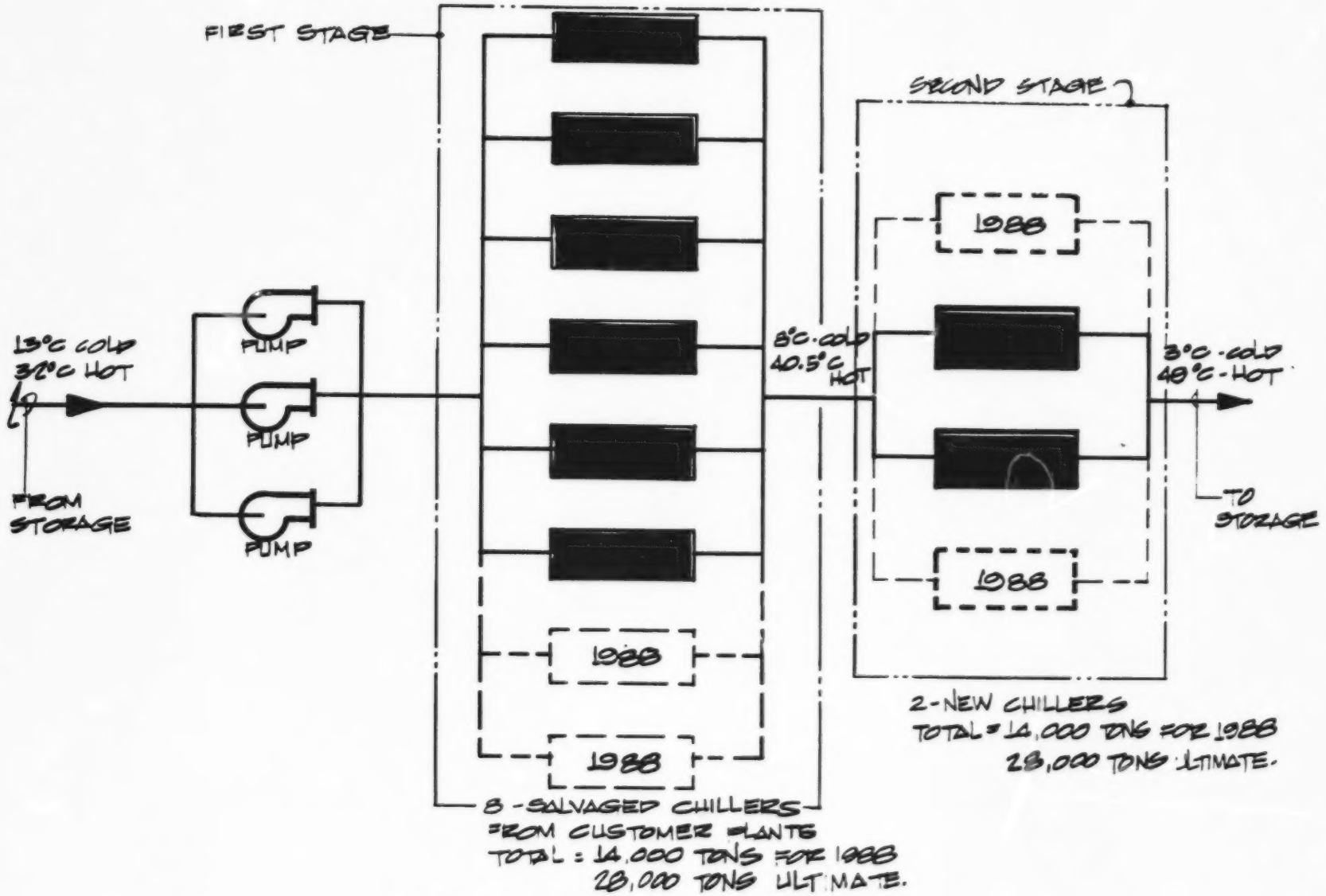


Fig. 28

STEAM DELIVERY PROFILES OF 4 MAJOR TORONTO SYSTEMS

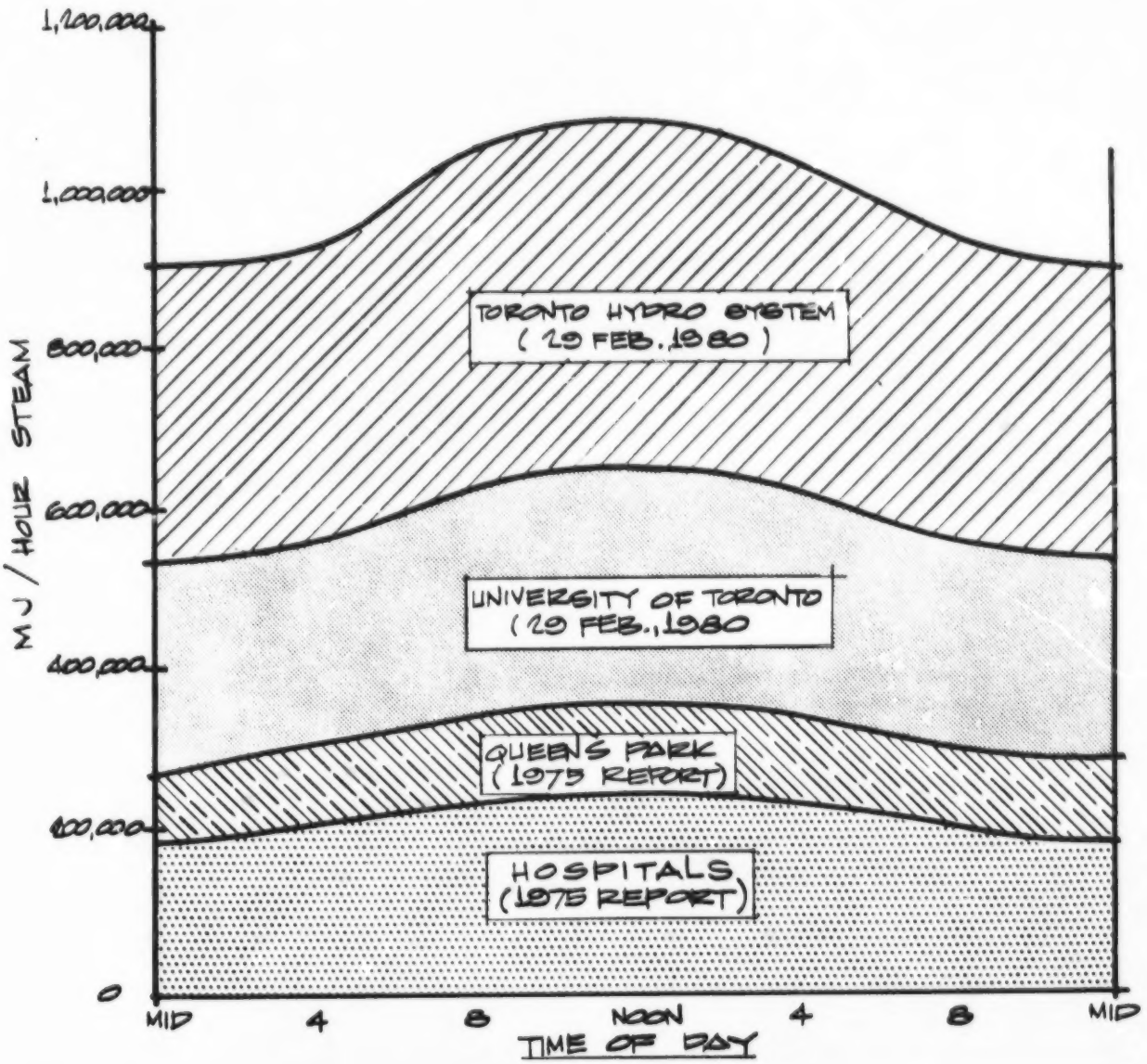


Fig. 29

TORONTO STEAM GRID
AFTER FREECOOL

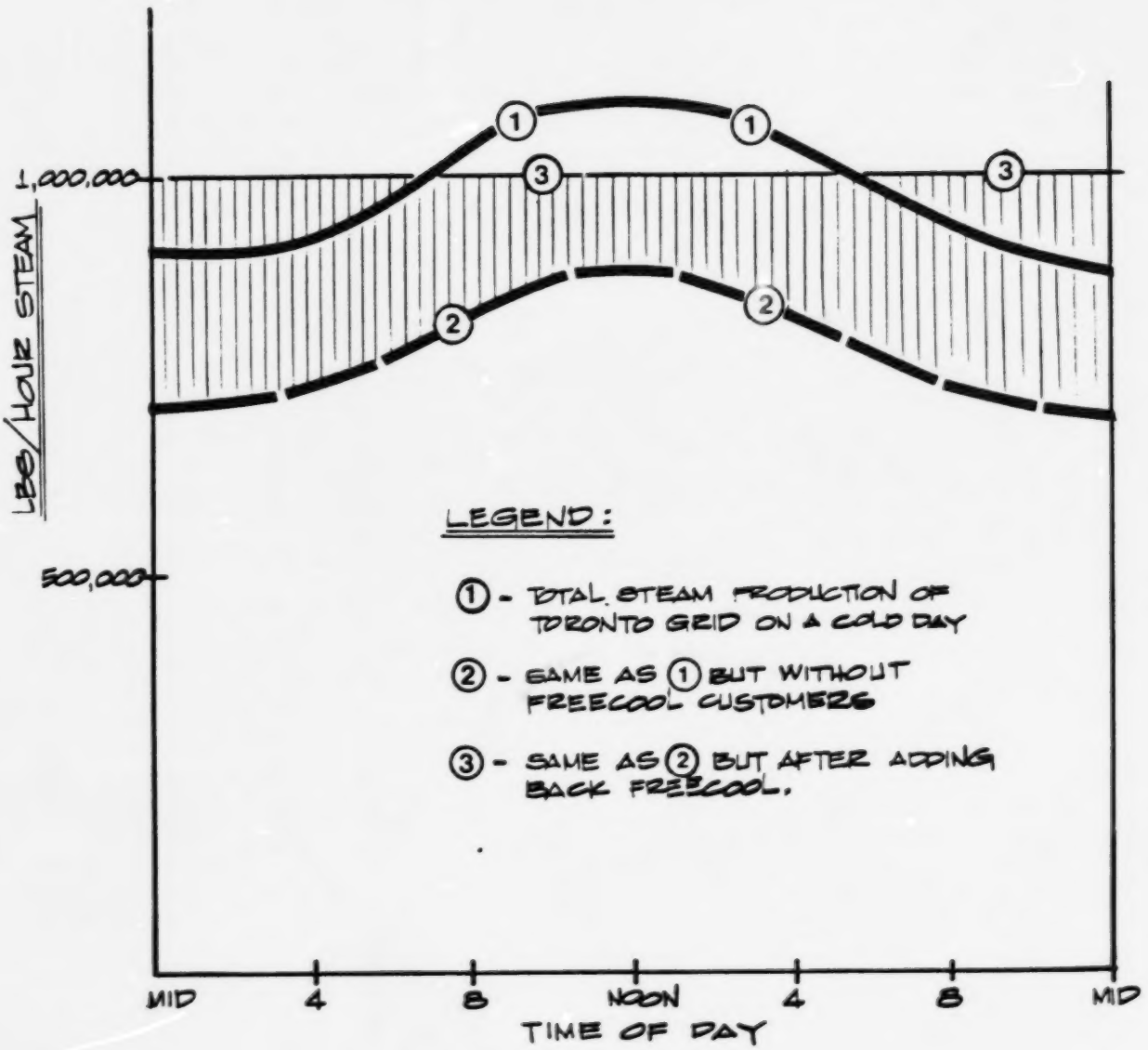


Fig. 30

TORONTO STEAM GRID AFTER ENERGY RETROFIT AND AFTER FREECOOL

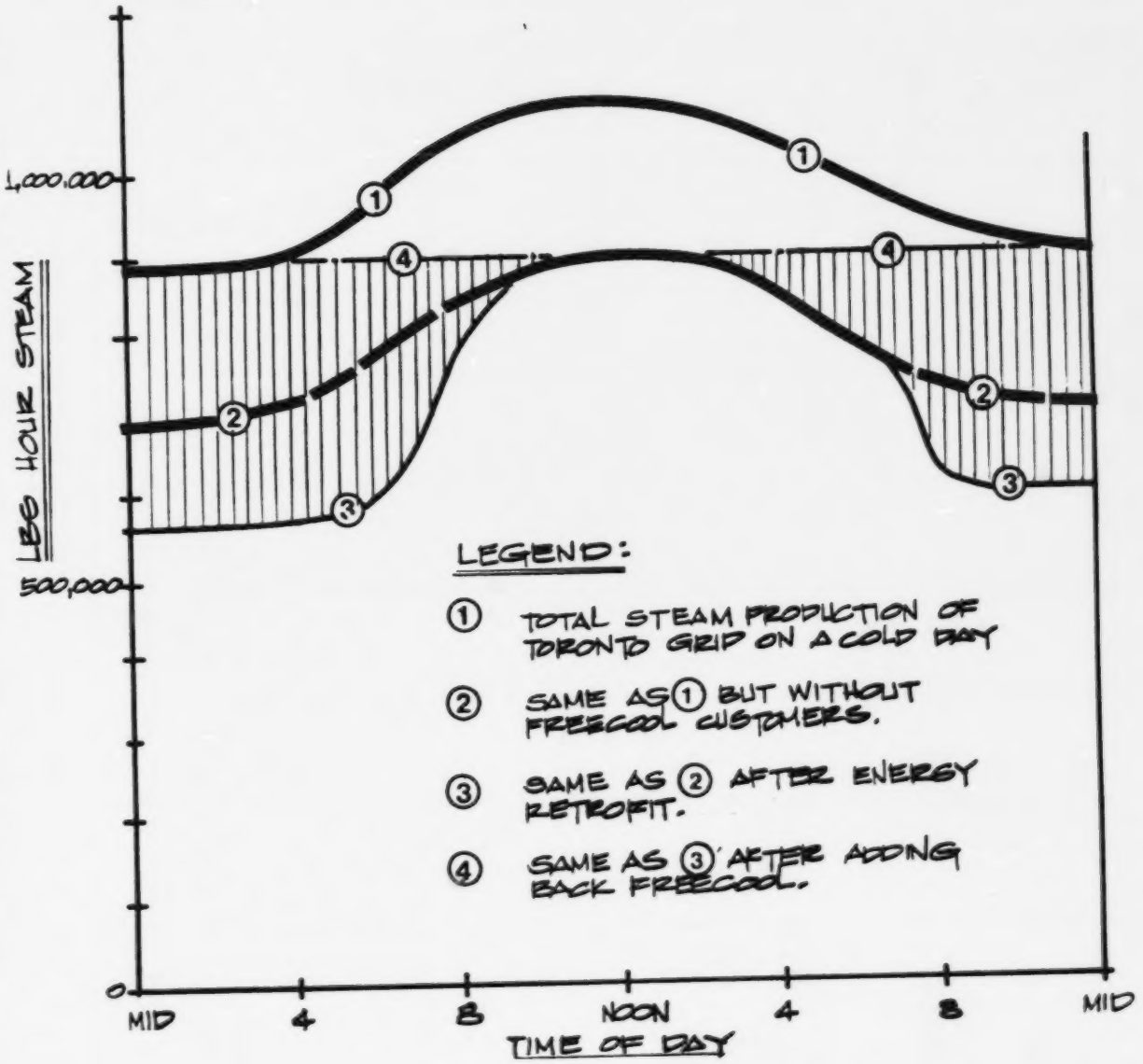


Fig. 31

ESTIMATE OF CAPITAL FOR FREECOOL COOLING

Item	Unit Cost	Value in 1981 M$								
		1981	1982	1983	1984	1985	1986	1987	1988-2000	Total
1981-1987 Construction										
Lakewater Intake						385				385
Intake Tunnel						14,641	4,334			18,975
Intake Pump House							5,995			5,995
Lakewater Pumps								2,750		2,750
Outlet Spillway								385		385
Chilled Water S/R Conduit							4,696	3,334		8,030
Risers and Valves								770		770
Pipe								121		121
Meters & Cent. Cont.								160		160
Control Valves								220		220
Branch Lines								2,860		2,860
Sub-total						15,026	15,025	10,600		40,651
Fees & Allowances										
Miscellaneous - 10%										
Engineering - 6%										
Legal - 1%										
Const. Mgt. - 6%										
Contingency - 10%										
Total - 37.315%				385	1,505	4,514	4,514	4,251		15,169
Sub-total				385	1,505	19,540	19,539	14,851		55,820
1987 Equipment Additions								1,650		1,650
Fees @ 37.315%								616		616
1988-2000 Extensions									2,579	2,579
Fees @ 37.315%									963	963
Total				385	1,505	19,540	19,539	17,117	3,542	61,628

Fig. 32

ESTIMATE OF CAPITAL FOR FREECOOL COOLING AND HEATING IN 1981 - M$

Item	1981	1982	1983	1984	1985	1986	1987	1988	1989-2001	Total
Initial Inst'n. 1981-1988										
3-17 MM gal. Storage Tanks					6,600	6,600	5,130			18,330
Chiller Building							3,520			3,520
Land & Rights of Way					4,400					4,400
Substation							1,210			1,210
Chillers:										
New 14,000 tons								2,700		2,700
Old 14,000 tons								770		770
Installation								825		825
Pumps, Piping, Wiring								3,850		3,850
Heating Conduit						3,810	1,140			4,950
Conn's., Meters, Lines, etc.						590		2,545		3,135
Sub-total					11,000	11,000	11,000	10,690		43,690
Fees @ 37.315%			543	2,172	3,257	3,257	3,290	3,784		16,303
Sub-total			543	2,172	14,257	14,257	14,290	14,474		59,993
1988 Equipment Addition										
New Chillers - 14,000 tons								2,700		
Installation								500		
Pumps, Piping, Wiring								2,047		
Sub-total								5,247		
Fees @ 37.315%								1,958		
Sub-total								7,205		7,205
1989-2001 System Extension										
Conn's., Meters, Lines									2,534	
Fees @ 37.315%									946	
Sub-total									3,480	3,480
Sub-total Heating			543	2,172	14,257	14,257	14,290	21,679	3,480	70,678
Sub-total Cooling			385	1,505	19,540	19,539	17,117		3,542	61,628
Total - Cooling & Heating							31,407	21,679	7,022	132,306

Fig. 33

ENERGY FOR FREECOOL COOLING

Existing On-Site Chillers

	Maximum kW		kWh x 1,000	
Month	1987	2000	1987	2000
January	23,000	44,000	6,000	12,000
February	27,000	52,000	6,000	12,000
March	42,000	81,000	7,000	14,000
April	50,000	96,000	9,000	17,000
May	58,000	112,000	10,000	19,000
June	70,000	135,000	14,000	27,000
July	71,000	137,000	17,000	33,000
August	71,000	137,000	16,000	31,000
September	65,000	125,000	14,000	27,000
October	59,300	114,000	10,000	19,000
November	35,000	68,000	7,000	14,000
December	31,000	60,000	6,000	12,000
Total	602,000	1,161,000	122,000	237,000
Annual Cost $'000 1981	$2,045,000	$3,945,000	$2,777,000	$5,359,000
		$4,822,000 1987	$9,304,000 2000	

Fig. 34

	Freecool			
	Maximum kW		kWh x 1,000	
	1987	2000	1987	2000
January	700	1,400	40	77
February	800	1,500	42	81
March	1,800	3,500	51	98
April	2,700	5,200	53	102
May	3,600	6,900	59	114
June	6,000	11,600	78	151
July	6,100	11,800	125	241
August	6,000	11,600	113	218
September	4,800	9,300	67	129
October	3,900	7,500	54	104
November	1,300	2,500	44	85
December	1,000	1,900	42	81
	38,700	74,700	768	1,481
$'000 1981	$132,000	$255,000	$18,000	$35,000
		$150,000	$290,000	
		1987	2000	

Status quo electric cost for cooling in the year 2000	$9,304,000
Lakewater electric cost for cooling in the year 2000	290,000
Cost avoidance in the year 2000	$9,014,000

Fig. 34(contd)

INTAKE COSTS IN 1980 DOLLARS

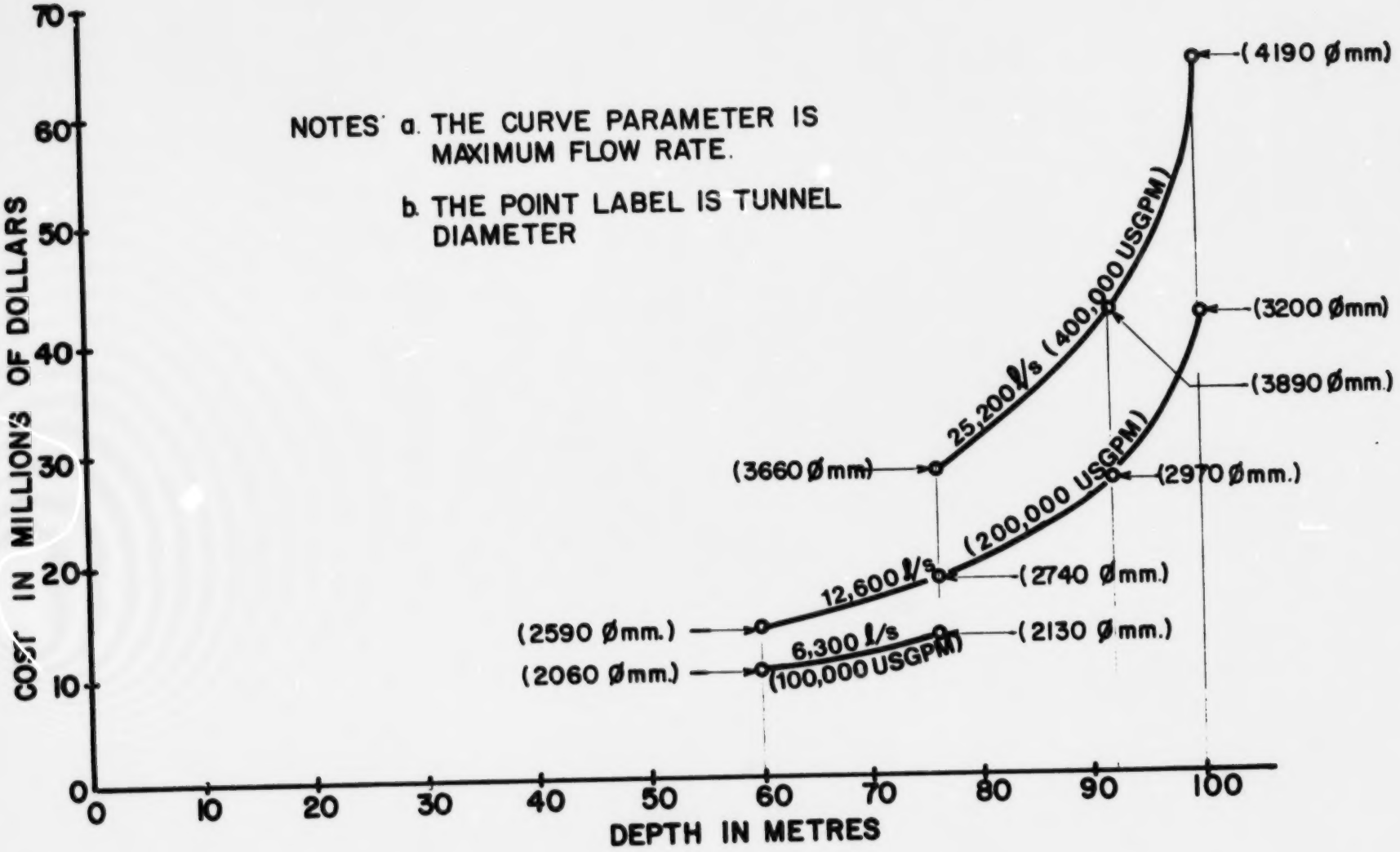


Fig. 35

APPENDIX A

Ontario

Ministry
of the
Environment

965-6954

1980 09 08

135 St. Clair Avenue West
Suite 100
Toronto, Ontario
M4V 1P5

Mr. R. T. Tamblyn
Engineering Interface Limited
Suite 200
2 Sheppard Avenue East
Willowdale, Ontario
N2N 5Y7

RECEIVED
SEP 18 1980
ENGINEERING INTERFACE LTD.

Dear Mr. Tamblyn:

RE: FREECOOL

Thank you for your letter of August 5, 1980 to Dr. R. Weiler. I have outlined below the regulatory approvals that would be required for a project of this nature and our general comments on the concept.

Licences under the Water Resources Act would be required for both the intake and discharge of water. An examination of the intake and discharge designs and locations would be required. The intake should be constructed to avoid high turbidity and to limit fish access. Safety would likely be the main concern at the discharge although temperature and water quality will also have to be considered. Procedures for the taking and discharge of cooling water are outlined in our publication "Water Management" (copy enclosed - refer to page 18). "Freecool" will draw less than 10 m^3/s and so scientific studies are not mandatory, but further discussions on this point should be pursued once your initial study is complete. The Environmental Assessment Act does not apply to Federal projects or to private projects unless they are specifically designated.

Generally, we see no major environmental concerns that would make this project unworkable. We expect that the discharge to the harbour would actually improve the water quality of the harbour.

If we can be of further assistance please don't hesitate to contact us again.

Yours sincerely,

S. L. Salbach, Assistant Director
Water Resources Branch

LM/mm
c.c. F. C. Fleischer, Attn: R. Weiler
V. Rudik, Environmental Approvals Branch
B. A. Singh, Central Region

water treatment services

33 GLEN CAMERON AVE., UNIT 7, THORNHILL, ONTARIO • TEL. 881-1298

September 19,1980

Engineering Interface Ltd.,
Suite 200,
Shephard Center,
Yonge and Shephard,
Willowdale, Ont.

APPENDIX B

Attention: Mr. R.T. Tamblyn, P. Eng.

Re: Free Cool

Dear Mr. Tamblyn,

This is in reply to your request for my comments as to the water treatment aspects of the above subject.

In my opinion, I would not use any form of water treatment other than straining to remove fish, etc. My reasons for this are as follows:

1. The amount of an effective treatment that would be necessary would cause environmental problems.

2. The cost of treating once-through water would be excessive.

3. The corrosion levels will be low because the oxygen levels will be lower at the depths in question.

In view of the above reasons, I would rather use non-ferrous piping such as concrete or PVC. The steel valves could be coated on their exposed surfaces.

Routine high pressure washing of the plate exchangers should provide all the treatment necessary,

Yours very truly,

Alan W. Stevens

RECEIVED

OCT 3 1980

ENGINEERING INTERFACE LTD